

Interim Report No. IR-76

PROPERTIES OF OPTICALLY TRANSPARENT ADHESIVES

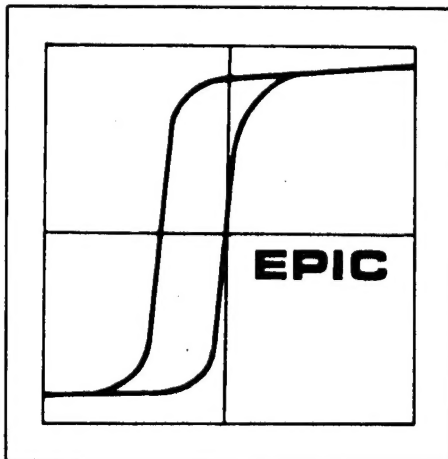
by

Walter H. Veazie

October 1970

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**E**LECTRONIC  
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**I**NFORMATION  
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## PREFACE

This interim report has been prepared from data collected by Mr. A.J. Moses, formerly of the Electronic Properties Information Center staff. The information provided by adhesive manufacturers and the Radiation Effects Information Center is gratefully acknowledged. The limited optical, mechanical, electronic and thermal properties data identified in the literature and the wide variation in processing data, presents a significant problem to the designer and producer of optical and electro-optical systems. This interim report provides those concerned with developing such systems with a compilation of available information and data. The format, scope and adhesives included will be modified and expanded if EPIC users express a continuing interest in these materials and properties.

# TABLE OF CONTENTS

PREFACE	i
TABLE OF CONTENTS	ii
INTRODUCTION	1
TRANSPARENT OPTICAL ADHESIVES-DATA SHEETS	
AO-805	5
ARALDITE 502	12
B & S No. 8	13
BEETLE 4128	14
CANADA BALSAM	15
CELLULOSE CAPRATE	17
CR-39 (PKR-15)	19
DOW CORNING 200	20
EASTMAN 910	21
ECCOBOND 24	22
ECCOGEL 1265	23
EPIKOTE 817	24
EPOCAST 253 (15 E)	25
EPOCAST H-1368/9313	26
EPO-TEK 301	28
EPO-TEK 305	31
EPOXY-20 ADHESIVE	31
GELVA	32
GLYCERINE	33
HE-2	34
HE-10	37
HE-63	40
HE-65	43
HE-79	43
HE-100 B	46
HE-100 X	46
HE-F-4	47
H.T. CEMENT	48
LENS BOND TYPE C-59	49
LENS BOND TYPE F-65	50
LENS BOND TYPE M-62	51
LENS BOND TYPE U-69	52
OPTICON SFA-23	53
OPTICON UV-57	54
ROSS OPTICAL CEMENT No. 24	55
RTV 602	56
RTV 615	61
STIXSO DD	67
STYCAST 1253	68
STYCAST 1264	69
STYCAST 1269 A	70
SYLGARD 51	71
SYLGARD 182	72
SYLGARD 184	74
URALANE X-87174 A/B	75
WYNDHAM OPTICAL CEMENT	75
XR-63-488	76
XR-63-489	78
BIBLIOGRAPHY	83
APPENDIX I MANUFACTURERS OF TRANSPARENT OPTICAL ADHESIVES	88



## INTRODUCTION

Optical and electro-optical systems applications where adhesives are used include: camera and television lenses, telescopes, wind tunnel optics, telescopic sights, range and height finders, periscopes, contour projectors, magnifiers and solar cell bonding. (1,2,3)\* Optical adhesives are used in a very low volume, but require an extremely high quality of material.

A review of optical adhesives by Katz (4) and laboratory studies by Hunt (5), Pellicori (6), and Turini (7) provide a major contribution to this interim report. Adhesives for optical applications are categorized as:

Optically Transparent Adhesives - used for bonding components in which the visual performance properties of the bonded area are not affected.

Optically Inactive Adhesives - used for attaching optical components to non-optically active fixtures.

Optical Identification Adhesives- used to adhere radioactive base identification systems. (1)

This interim report deals with the first category of optically transparent adhesives that are used for:

Reduction of the number of glass- or plastics-to-air surface interfaces in multiple lens systems.

Joining lens components of different refractive indices.

Convenience in handling multi-element lens systems.

Military specifications which apply to optically transparent adhesives as reviewed by Katz (1) include:

Glass Adhesives

MIL-O-13830

MIL-A-003920

MIL-S-14195

Plastics Adhesives

MIL-A-8576

MIL-P-25055

General Purpose Adhesives

MIL-A-46050

MIL-B-3469

The periodic and Government report literature only nominally supplement the limited property data provided by the manufacturers of optically transparent adhesives. Additional data are needed in order to provide a basis for comparing the various adhesives included in this compilation. The properties

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\*Numbers in parenthesis refer to documents listed in the Bibliography at the end of this report.

identified by Hunt (5) which are significant in selecting an optical adhesive include:

- High visible light transmission.
- Satisfactory refractive index, usually 1.52 - 1.54.
- Colorless or nearly so.
- Capable of laboratory preparation in quantity to desired cleanliness and viscosity.
- Homogeneity throughout the cement layer and freedom from strain in the finished assembly.
- Little shrinkage on curing.
- Resistant to thermal shock.
- Stable over the temperature range -70°C to +70°C.
- Resistant to mechanical shock.
- Resistant to ultra-violet light.
- Resistant to moisture.
- Resistant to fungal attack.
- Chemically stable.
- Chemically inert to glass surfaces.
- Adequate adhesion.
- Suitable for truing operations.
- Decementing should not be unduly difficult.
- Non-toxic.
- Should present no difficulties of transportation or storage.

It is evident from the data presented in this interim report that the optical system designer must secure additional property data in order to assure the successful operation of his system.

The forty-eight adhesives which are included in this interim report are arranged in the following alpha-numeric order according to the trade or composition designation used by the manufacturer or supplier:

AO-805	HE-100 B
ARALDITE 502	HE-100 X
B & S No. 8	HE-F-4
BEETLE 4128	H.T. CEMENT
CANADA BALSAM	LENS BOND TYPE C-59
CELLULOSE CAPRATE	LENS BOND TYPE F-65
CR-39 (PKR-15)	LENS BOND TYPE M-62
DOW CORNING 200	LENS BOND TYPE U-69
EASTMAN 910	OPTICON SFA-23
ECCOBOND 24	OPTICON UV-57
ECCOGEL 1265	ROSS OPTICAL CEMENT No. 24
EPIKOTE 817	RTV 602
EPOCAST 253 ( 15 E)	RTV 615
EPOCAST H-1368/9313	STIXSO DD
EPO-TEK 301	STYCAST 1263
EPO-TEK 305	STYCAST 1264
EPOXY-20 ADHESIVE	STYCAST 1269 A
GELVA	SYLGARD 51
GLYCERINE	SYLGARD 182
HE-2	SYLGARD 184
HE-10	URALANE X-87174 A/B
HE-63	WYNDHAM OPTICAL CEMENT
HE-65	XR-63-488
HE-79	XR-63-489

Data on chemical type or composition, processing and properties have been included when available. All optical data that has been identified in the literature or provided by the manufacturer has been reproduced in this interim report. References briefly noted on each data sheet are fully identified in the Bibliography at the end of the report. Unless otherwise identified, data were obtained from the manufacturer's literature.

The Bibliography at the end of this report is organized in two sections:

Periodic and Report Literature - Includes references noted in the introduction and other citations.

Manufacturers Literature - Includes citations to sources of data used.

Appendix I provides a listing of the manufacturers and the optical adhesives which they supply.

TRANSPARENT  
OPTICAL ADHESIVES  
DATA SHEETS

## AO-805

Chemical Type or Composition: Partially polymerized thermoplastic cement

Manufacturer: American Optical Co.

### PROCESSING DATA

Shelf Life: 1 month in refrigerated storage at 5°C

Cure Times: 3 hours at 79°C

Decementing: Heat to 107°C for 30 minutes, twist to separate. Remaining cement may be removed with acetone.

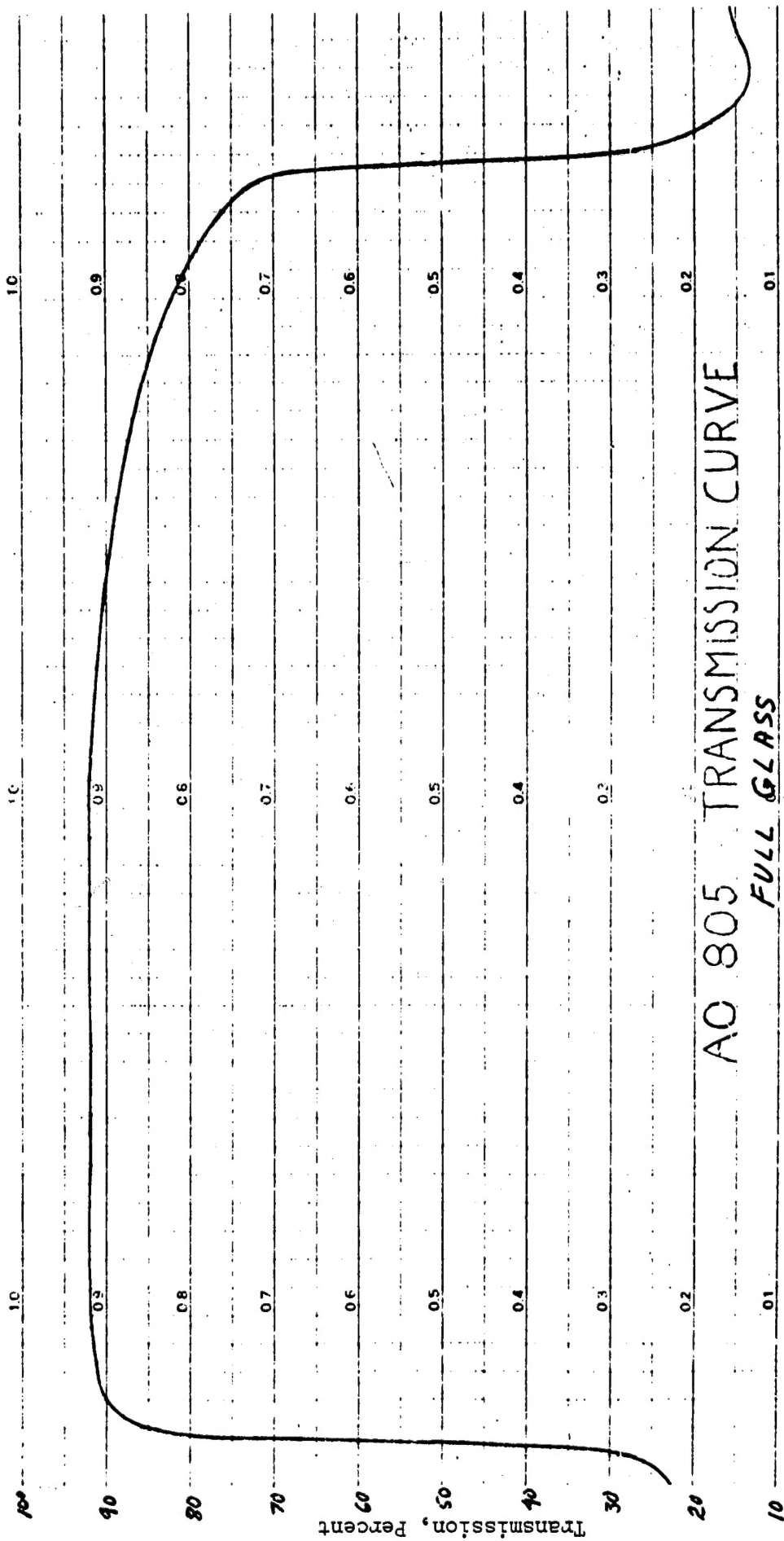
Service Temperature: -54°C to 71°C for 22 hours or soaking in distilled water at 38°C per MIL-A-3920A. (1) Failure was found in flat pyrex and plate glass samples cemented together with AO-805 when subjected to temperatures between 0 and -20°C (2) No change was found at 65°C. (2)

### OPTICAL PROPERTIES

Refractive Index: 1.49

Clarity: Clear

- 
1. American Optical Co., Vendor Literature
  2. Turini



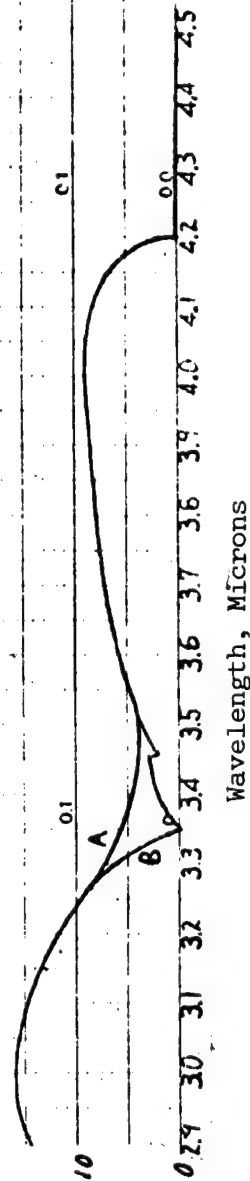
Wavelength, Microns  
(Continued on Next Page)

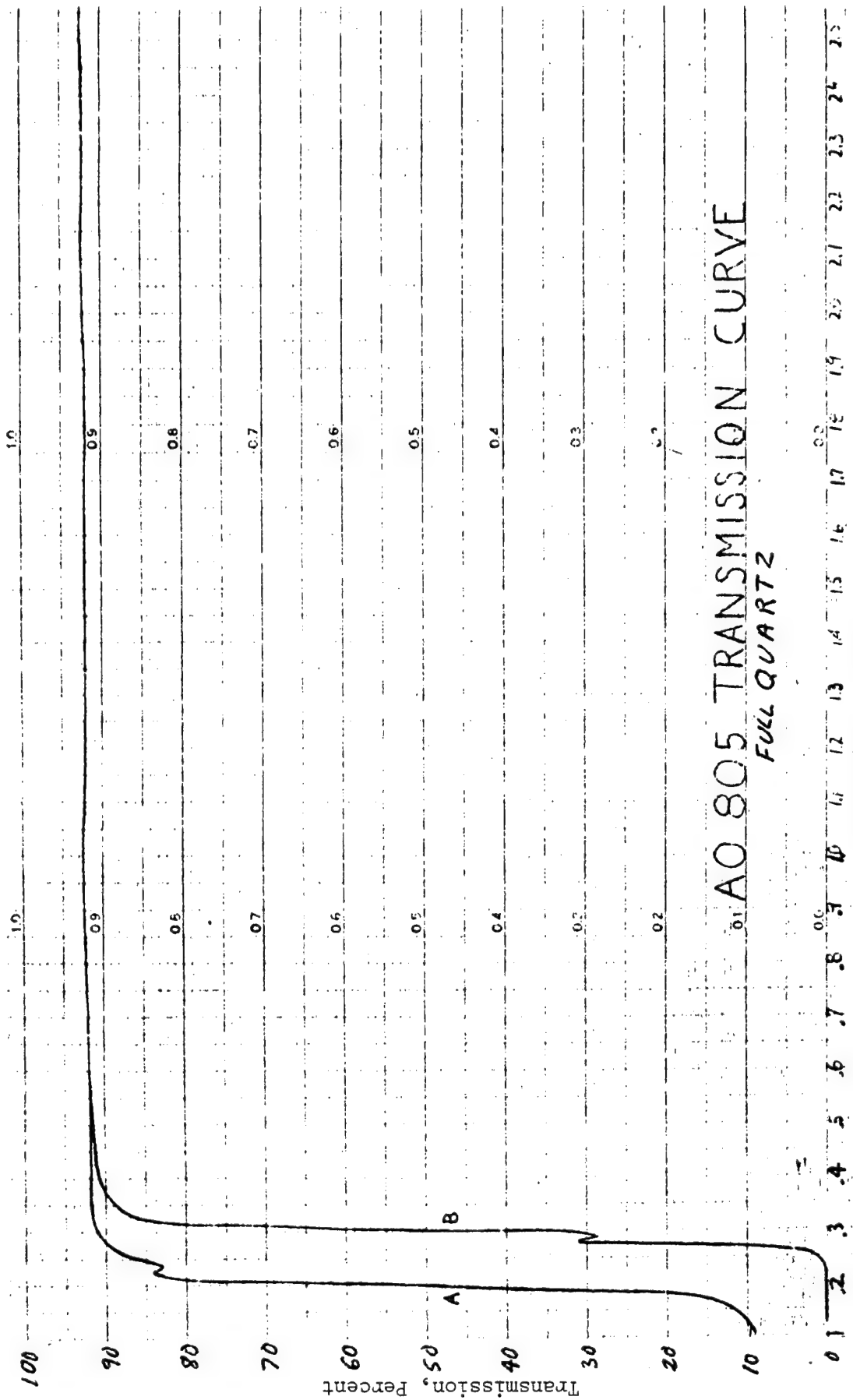
100 10 10  
 90 09 09  
 80 08 08  
 RANGE: FULL GLASS TRANSMISSION  
 07 PIECES: A GLASS DISK 3.97% THICK  
 B GLASS DOUBLET (CEMENTED  
 WITH AG 805) 3.97% THICK  
 06

OBSERVATION: AG 805 TRANSMITS OVER  
 THE FULL USEFUL TRANSMISSION  
 RANGE OF GLASS  
 05

04  
 COMPOSITE OF SHORTER RANGE  
 TRACES DRAWN 8/24/66  
 03

02  
 01  
 00

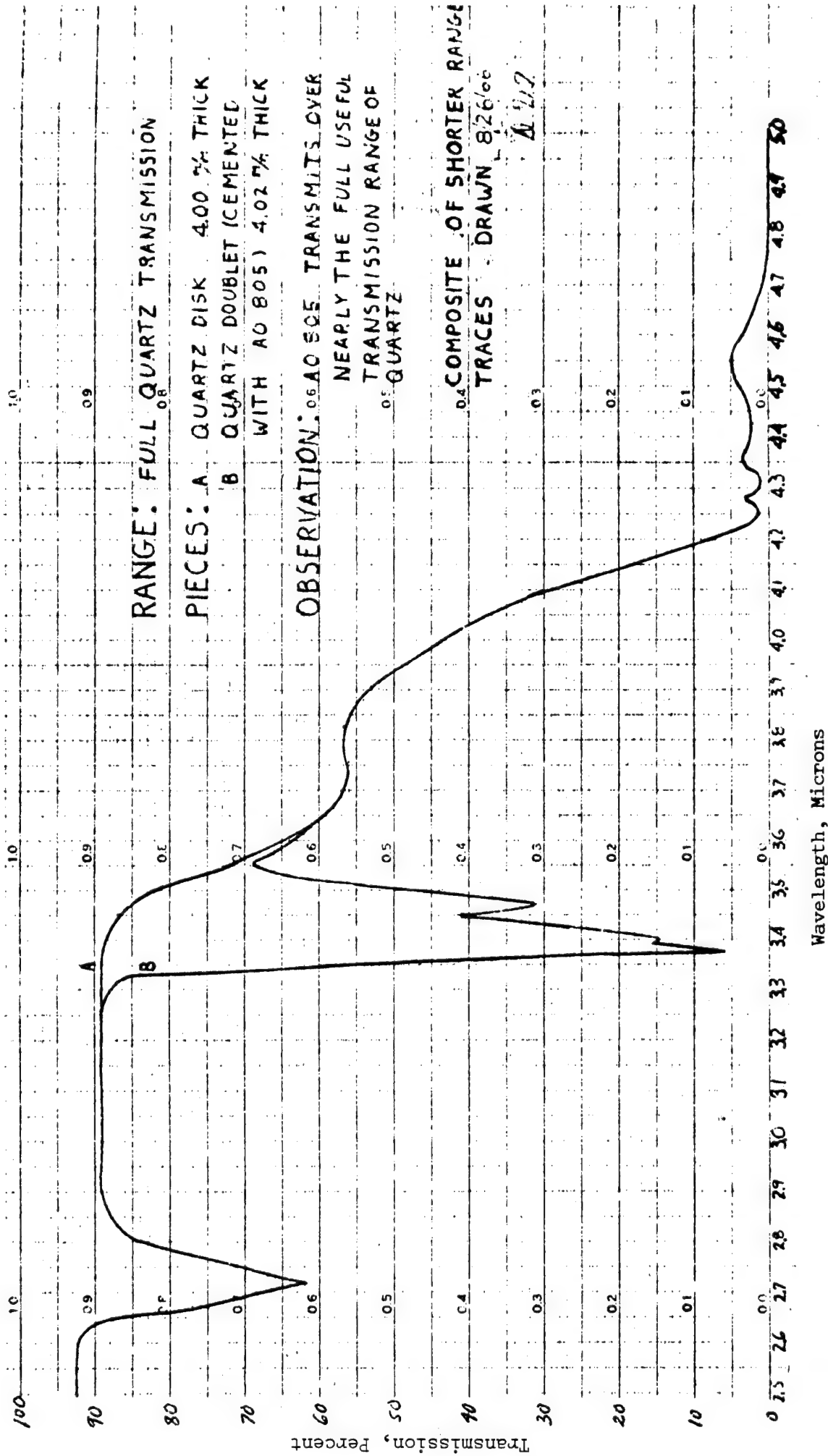




Wavelength, Microns

(Continued on Next Page)





RANGE: FULL QUARTZ TRANSMISSION

PIECES: A QUARTZ DISK 400 % THICK  
 B QUARTZ DOUBLET (CEMENTED WITH AO 805) 4.02 % THICK

OBSERVATION: 0.6 AO 805 TRANSMITS OVER NEARLY THE FULL USEFUL TRANSMISSION RANGE OF QUARTZ

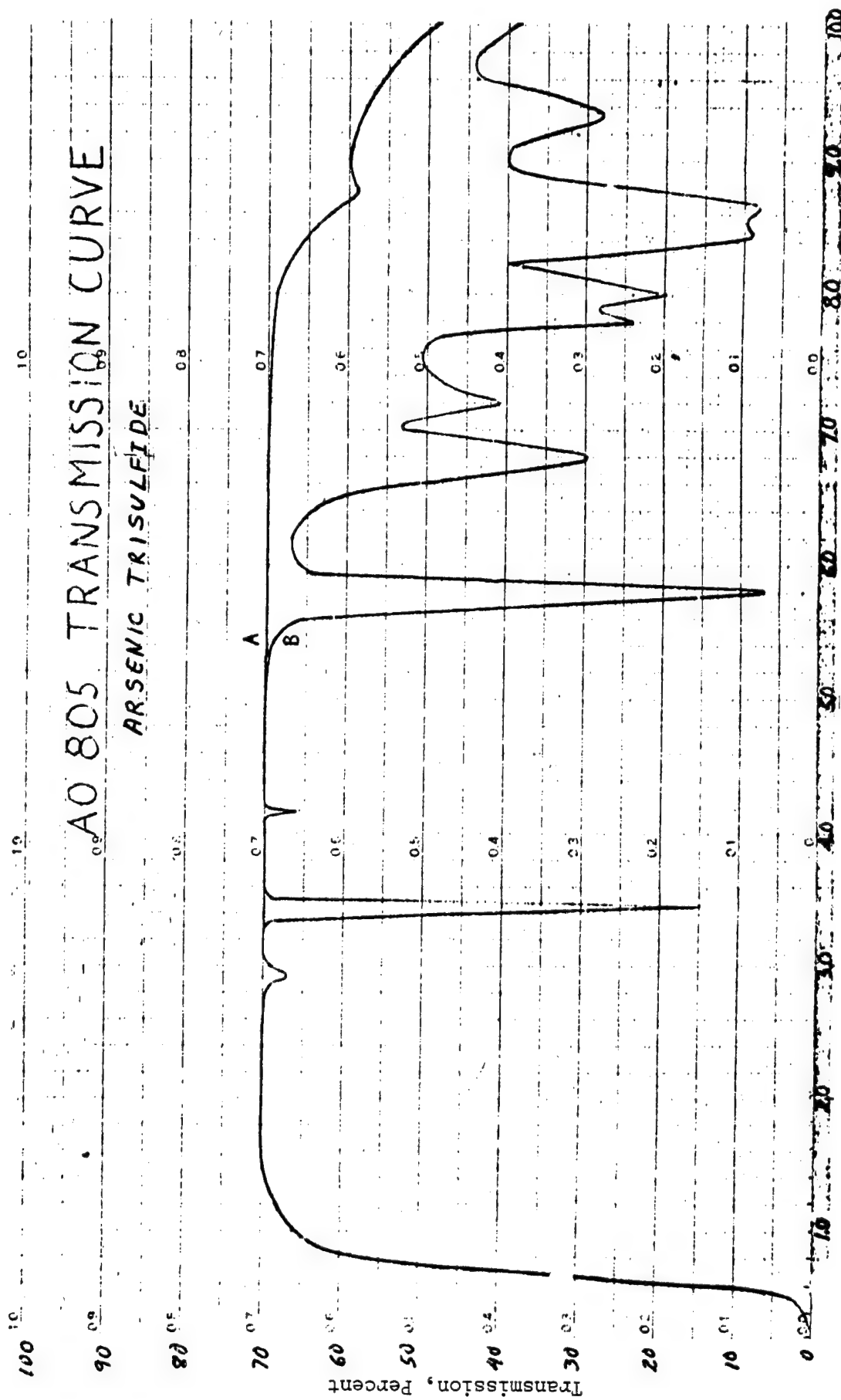
COMPOSITE OF SHORTER RANGE TRACES DRAWN 8/26/66

A 22

Wavelength, Microns

Transmission, Percent

ARSENIC TRISULFIDE



Wavelength, Microns

(Continued on Next Page)

100 10 09 09

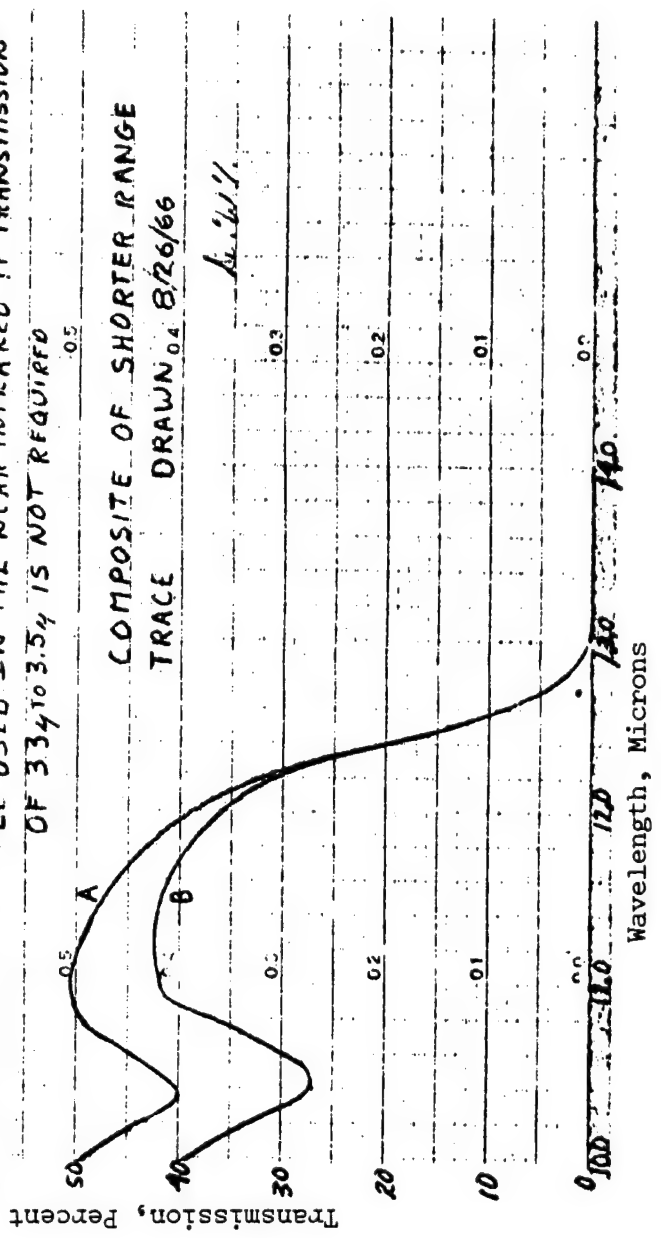
RANGE: FULL ARSENIC TRISULFIDE TRANSMISSION

PIECES: 0.08A ARSENIC TRISULFIDE DISK 4003% THICK

0.07 B ARSENIC TRISULFIDE DOUBLET (CEMENTED WITH AO 805 3.76% THICK 0.07)

OBSERVATION: AO 805 DOES NOT TRANSMIT WELL

PAST 5.54 IN THE INFRARED IT COULD BE USED IN THE NEAR INFRARED IF TRANSMISSION OF 334 TO 3.54 IS NOT REQUIRED



## ARALDITE 502

Chemical Type or Composition: Epoxy, 2-component system. Araldite 6010 diluted with 17% Dibutyl phthalate (1) or 10 parts by weight of Hardener 951 to 100 parts of Araldite 502 (2) or 20 parts by weight of Hardener 956 to 100 parts of Araldite 502 (2) or 35 parts by weight of LANCAST-A to 100 parts of Araldite 502 (2).

Manufacturer: CIBA Products Co.

### PROCESSING DATA

Pot Life: 100 gm mixture of Araldite 502 and Hardener 951 will gel in 30-50 minutes at 25°C.

Viscosity: At 25°C, 2100-3600 centipoise

Cure Times: 3 to 7 days at room temperature or 16-24 hours at 40°C or 2-8 hours at 100°C.

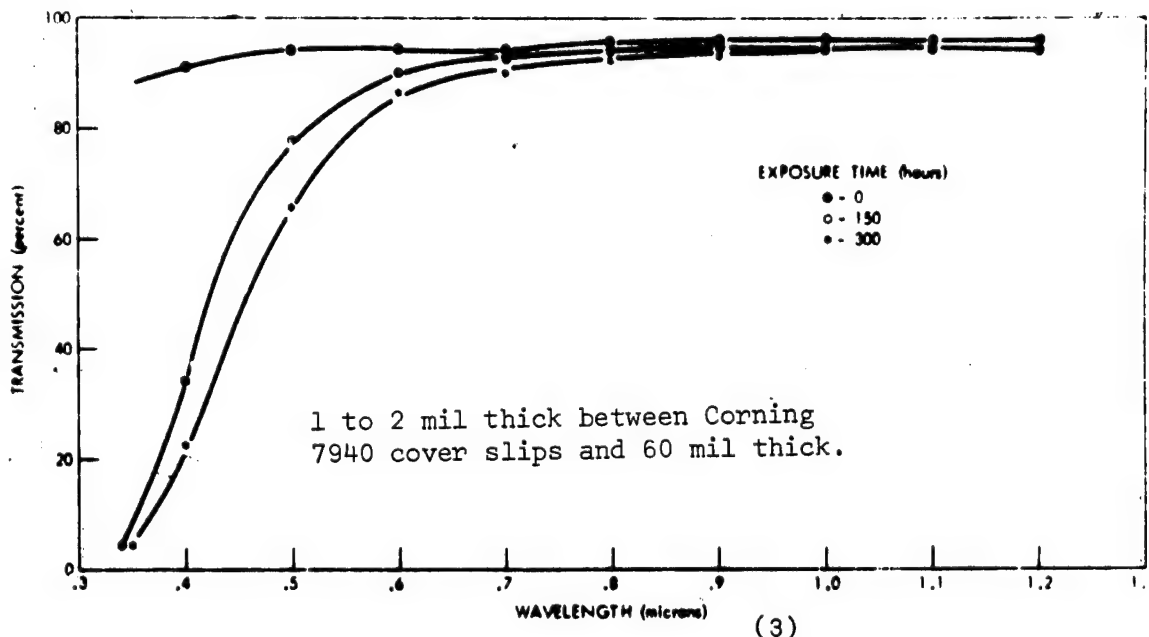
### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: At 25°C with Hardener 951 or 956, 8,000 psi  
Flexural Strength: At 25°C with Hardener 951 or 956, 14,000 psi  
Compressive Strength: At 25°C with Hardener 951 or 956, 16,000 psi  
Elongation: At 25°C with Hardener 951 or 956, 12.2%

Dielectric Constant: At 25°C with Hardener 951 at 60 Hz - 4.1,  $10^6$  Hz - 3.8  
Dissipation Factor: At 25°C with Hardener 951 at 60 Hz - 0.014,  $10^6$  Hz - 0.020  
Volume Resistivity: At 85°C with Hardener 951,  $1.2 \times 10^{16}$  ohm-cm  
At 100°C with Hardener 951,  $1.8 \times 10^{10}$  ohm-cm  
At 149°C with Hardener 951,  $2.2 \times 10^8$  ohm-cm

### OPTICAL PROPERTIES

Clarity: Light straw colored



1. Handbook of Epoxy Resins
2. CIBA Vendor Literature
3. Haynos

Chemical Type or Composition: Thermosetting, three-component system

Manufacturer: Barr and Stroud, Ltd.

#### PROCESSING DATA

Shelf Life: 1 year under refrigerated conditions. 5 hours at 20°C.

Cure Times: 6 hours at 60°C or 3 hours at 80°C.

Decementing: Castor oil at 280°C or 300°C for 3 hours, cool to 90°C and slide apart.

Service Temperature: -50 to 80°C

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 281 kg/cm<sup>2</sup> (3)

Shrinkage: 1.0 %

Weight Loss: Negligible

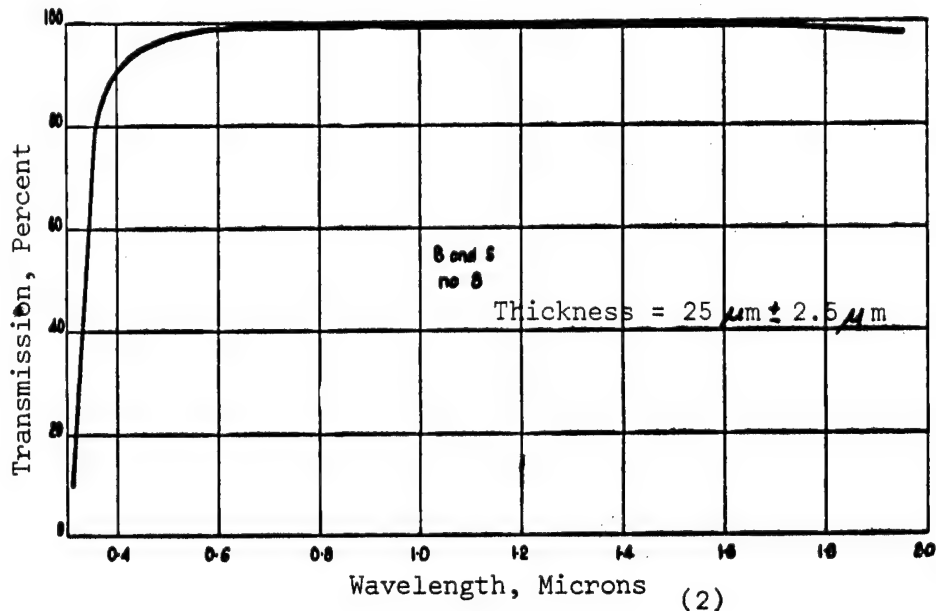
Coefficient of Thermal Expansion:  $7 \times 10^{-5}/^{\circ}\text{C}$

Thermal Shock Resistance: Unaffected by cycling at 70°C for 2 hours, -74°C for 2 hours, 70°C for 2 hours to room temperature.

#### OPTICAL PROPERTIES

Refractive Index: 1.586

Clarity: Yellow color



1. Barr & Stroud, Ltd., Vendor Literature
2. Hunt
3. Unit used by Hunt

## BEETLE 4128

Chemical Type or Composition: Polyester, thermosetting; two-component system is hot setting while the three component system is cold setting.

Manufacturer: B.I.P. Chemicals Ltd.

### PROCESSING DATA

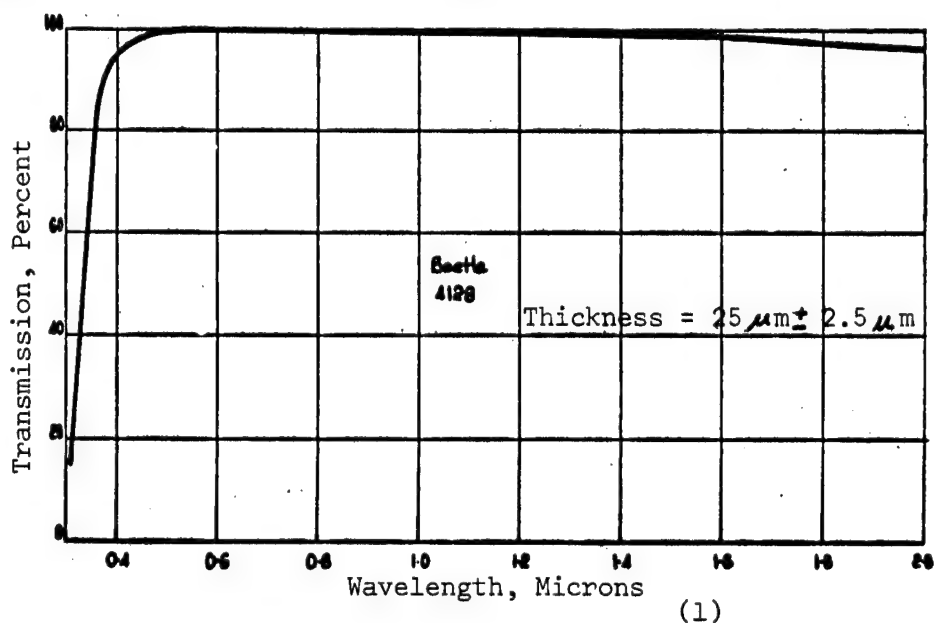
Shelf Life: 4 months in closed containers stored at 20°C  
Pot Life: Mixed cold setting 1 1/2 hours  
Cure Times: Two-component system 18 hours at 80°C. (1)  
Three component system 24 hours at room temperature or 3 hours at 60 to 80°C. (1)  
Service Temperature: 100°C (2)  
Decementing: Heat in water to 70°C (1)

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 300 lbf/in.<sup>2</sup> (1)  
Shrinkage: 1.5 % (1)  
Hardness: 50 Barcol (Type 934/1) (2)  
Weight Loss: Negligible (1)  
Dielectric Strength: At 25°C - 370 volts/mil, At 90°C - 400 volts/mil (ASTM D-149)  
Dielectric Constant: At 1 MHz - 3.13 (ASTM D-150) (2)  
Dissipation Factor: At 1 MHz - 0.002 (ASTM D-150) (2)  
Linear Coefficient of Thermal Expansion:  $\alpha = 6.6 \times 10^{-5} / ^\circ\text{C}$  (1)  
Thermal Shock Resistance: Unaffected by cycling at +70°C for 2 hours, -74°C for 2 hours, +70°C for 2 hours to room temperature. (1)

### OPTICAL PROPERTIES

Refractive Index: 1.55 (1)  
Clarity: Clear, light straw-colored liquid (2)



1. Hunt. Note should be made of the original units used by Hunt.
2. B.I.P. Chemicals Ltd., Vendor Literature

## CANADA BALSAM

Chemical Type or Composition: Oleoresin, derived *Abies balsamea* (balsam fir).

Manufacturer: Cominso Ltd., Fisher Scientific Co.

### PROCESSING DATA

Viscosity: At 37°C 60-100 centipoises (70% xylene solution) (3)

Decementing: Accomplished by application of dry heat or by heating in a suitable solvent (e.g., ether, chloroform, turpentine, xylene, benzene, ethyl acetate).

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Bond Shear Strength: 440 lbf/in<sup>2</sup> (1)

Thermal Conductivity: At ~ 25°C,  $11 \times 10^{-4}$  watt/cm°C (Solid) (4)  
At 4°C,  $11.5 \times 10^{-4}$  watt/cm°C (Liquid) (4)

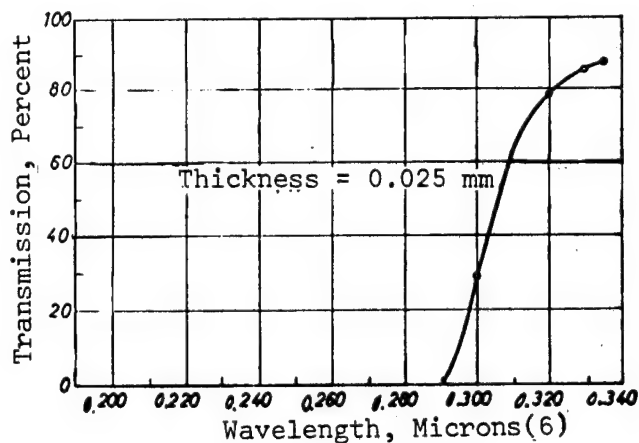
### OPTICAL PROPERTIES

Refractive Index: 1.54 (solid Canada Balsam) (1)

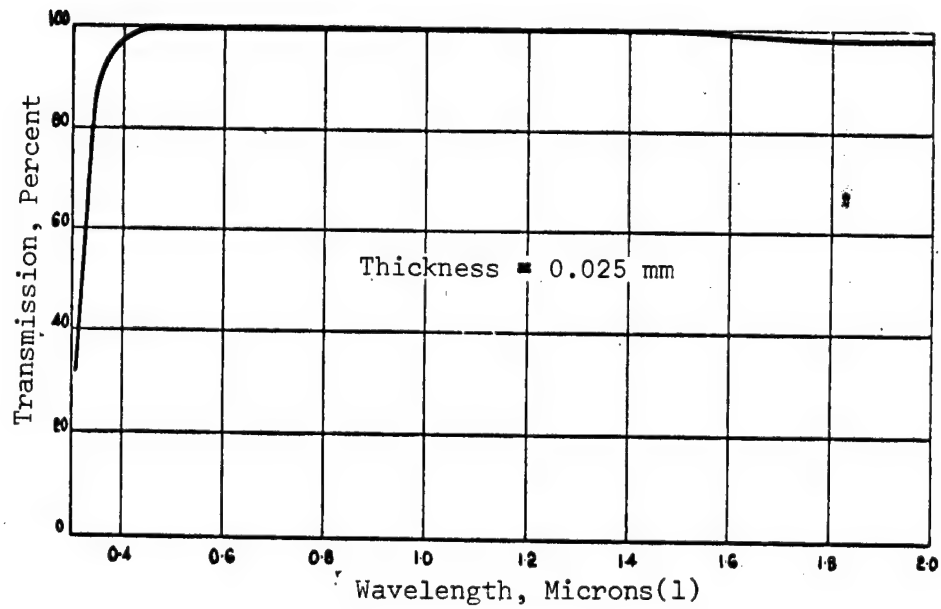
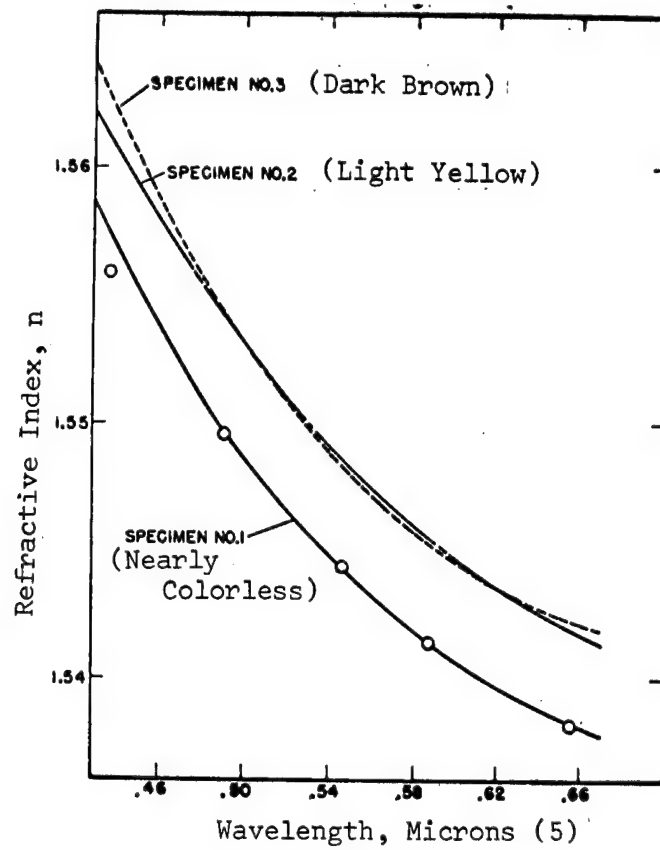
1.53 (soft Canada Balsam) (1)

1.530 (Canada Balsam D) (2)

Clarity: Pale yellow or greenish yellow. Transparent viscous liquid which dries slowly to a transparent varnish on exposure to air.



1. Hunt. Original units reported by Hunt are given.
2. Kaye
3. MIL-C-3469C
4. Washburn
5. Saunders
6. Pellicori





## CELLULOSE CAPRATE

**Chemical Type or Composition:** Thermoplastic

**Manufacturer:** Maas and Waldstein Co. (1)

### PROCESSING DATA

**Decementing:** Dry heat at 100°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

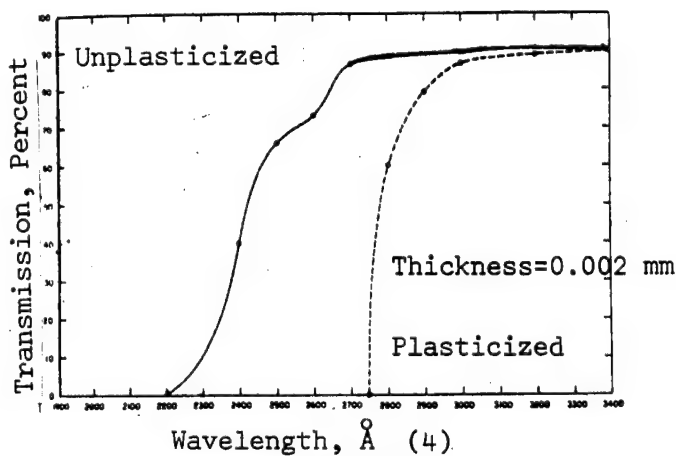
**Tensile Strength:** 300 lbf/in<sup>2</sup> (2)

**Thermal Shock Resistance:** Slight hair line cracks after cycling for 2 hours at +70°C, -74°C for 1/2 hour, -70°C for 2 hours, room temperature.

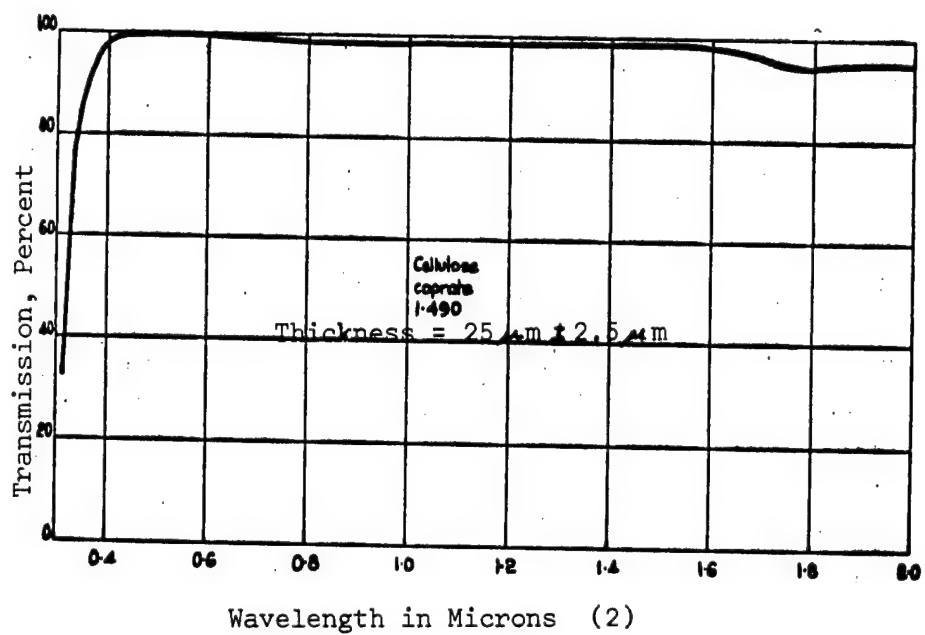
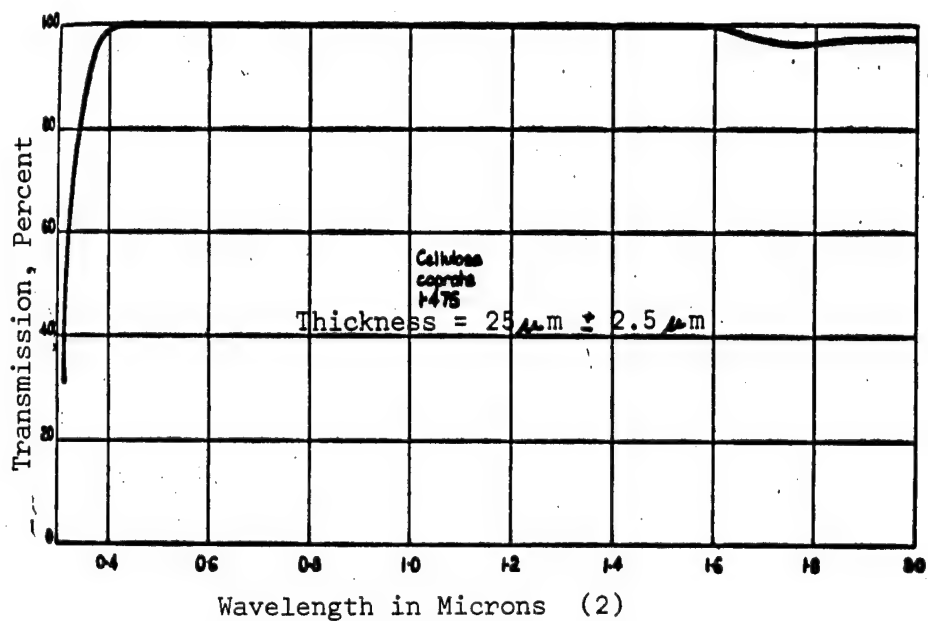
### OPTICAL PROPERTIES

**Refractive Index:** 1.49 (plasticized) (2), 1.473 (3)

**Clarity:** Pale Yellow



1. Adhesives Red Book, 1968
2. Hunt. Hunt's units were used in the compilation.
3. Kaye
4. Pellicori



## CR-39 (PKR-15)

Chemical Type or Composition: Allyl diglycol carbonate, two-component system, thermosetting.

Manufacturer: PPG Industries, Inc., Chemical Division

### PROCESSING DATA

Shelf Life: Refrigerated storage at 5°C

Cure Time: 8 hours at 80°C

Service Temperature: -40 to 100°C (1)

Decementing: Acetone if only partially polymerized. Cemented lenses can be separated by heating to 250 - 275°C or by immersion in acetone, or by soap, water and ammonia under pressure in an autoclave. (1)

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 25°C, 1.32 (2)

Tensile Strength: 5,000 - 6,000 psi (2)

Ultimate Compressive Strength: 22,500 psi (2)

Hardness: M95 - M100 Rockwell (2)

Thermal Conductivity: 1.45 Btu/hr/ft<sup>2</sup>/in/°F (2)

Linear Coefficient of Thermal Expansion:

At -40°C to 25°C,  $8.1 \times 10^{-5}/^{\circ}\text{C}$  (2)

At 25°C to 75°C,  $11.4 \times 10^{-5}$  (2)

At 75°C to 125°C,  $14.3 \times 10^{-5}$  (2)

### OPTICAL PROPERTIES

Refractive Index: At 27°C, 1.458 (1): 1.504 (2)

Clarity: Optically Clear (2)

Light Transmission: 92 % from 400 m $\mu$  to 700 m $\mu$  for cover glasses cemented with CR-39. For 1/4-inch thick CR-39, 92.2 % from 480 to 700 m $\mu$ . 82.5 % at 400 m $\mu$ . (1)

Dispersion Factor: 57.8 (2)

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1. Coles

2. PPG Industries, Inc., Vendor Literature

Chemical Type or Composition: Silicone fluid

Manufacturer: Dow Corning

#### PROCESSING DATA

Shelf Life: 24 months

Viscosity: 100 centistokes (also available in viscosities of 5 to 1000 centistokes)

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 25°C, 0.960

Dielectric Strength: 430 volts/mil

Dielectric Constant: At 100 Hz - 2.68, at 1 MHz - 2.68

Dissipation Factor: At 100 Hz - 0.00002, at 1 MHz - 0.00001

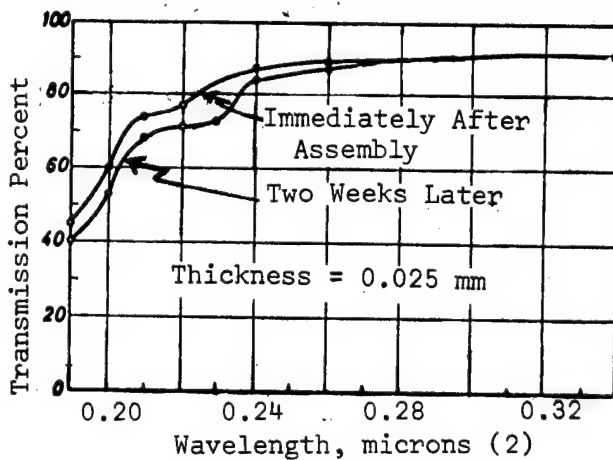
Volume Resistivity:  $1.0 \times 10^{14}$  ohm-cm

Thermal Conductivity: From 25 to 100°C,  $3.7 \times 10^{-4}$  cal/cm<sup>2</sup>-sec-(°C/cm)[Cenco-Fitch]

Volume Expansion: From 25 to 100°C,  $10.7 \times 10^{-4}/^\circ\text{C}$

#### OPTICAL PROPERTIES

Refractive Index: At 25°C, 1.40



1. Dow Corning Vendor Literature
2. Pellicori

## EASTMAN 910

Chemical Type or Composition: 90% methyl 2-cyanoacrylate and 10% thickening agent, plasticizer and stabilizer

Manufacturer: Eastman Kodak Company

### PROCESSING DATA

Viscosity: At 25°C, 60 - 300 centipoise (Brookfield)

Cure Times: Bond formation commences in 10 seconds to 2 minutes at room temperature.

Service Temperature: -54 to 74°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 27°/4°C, 1.0959

Tensile Strength: 3,900 psi (ASTM D-638)

Elongation: 6 % (ASTM D-638)

Dielectric Constant: At 1 Mc-3.34 (ASTM D-150-54 T)

Dissipation Factor: At 1 Mc-2.02 (ASTM D-150-54 T)

Thermal Conductivity: 121°C, 2.1 BTU in/hr ft<sup>2</sup> °F  
7.23 x 10<sup>-4</sup> cal/cm<sup>2</sup>/sec/°C/cm

### OPTICAL PROPERTIES

Refractive Index: 1.4517

Clarity: Cloudy, colorless liquid

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1. Eastman Kodak Co., Vendor Literature

**Chemical Type or Composition:** Epoxy, 2-components

**Manufacturer:** Emerson and Cuming, Inc.

**PROCESSING DATA**

**Pot Life:** 30 minutes at room temperature

**Viscosity:** 800 centipoise

**Cure Times:** 1 to 3 hours at room temperature - 16 to 24 hours for full cure

**Service Temperature:** 121°C (1). Pyrex and EDF-4 glasses joined with Eccobond 24 failed at -40°C. The application was for use in a 6.0 inch, T/1.5 LLL TV lens system. (2)

**MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES**

**Bond Strength:** > 1800 psi

**Dielectric Strength:** 420 volts/mil

**Volume Resistivity:**  $10^{14}$  ohm-cm

**Thermal Expansion:**  $40 \times 10^{-6} / ^\circ\text{F}$

**OPTICAL PROPERTIES**

**Refractive Index:** 1.54

**Clarity:** Clear

- 
1. Emerson & Cuming Vendor Literature
  2. Turini

## ECCOGEL 1265

Chemical Type or Composition: Epoxy 2-components

Manufacturer: Emerson and Cuming, Inc.

### PROCESSING DATA

Pot Life: 10 hours at room temperature

Viscosity: 620 centipoise

Cure Times: 3 days at room temperature or 48 hours at 43°C or 16 hours at 66°C or 4 hours at 93°C.

Service Temperature: 150°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.08

Shear Strength: 100 psi

Hardness: Shore A: 155°C=28, 25°C=25, -60°C=90

Dielectric Strength: 330 volts/mil

Dielectric Constant: At 25°C at 60 Hz to 10 GHz -  $\sim 3.0^*$

Dissipation Factor: At 25°C at 60 Hz to 10 GHz -  $\leq 0.02^*$

Volume Resistivity: At 25°C,  $10^{12}$  ohm-cm<sup>\*</sup>

Thermal Shock: Lens joined by Eccogel 1265 survived eight cycles from +65°C to -65°C. (2)

\* change substantially at temperatures over 66°C

### OPTICAL PROPERTIES

Refractive Index: 1.5

Clarity: Clear

Light Transmission: Spectral transmission of a 0.001-inch thick layer of Eccogel 1265 was measured at Mellon Institute. The transmission is essentially flat from the glass cut-off (approximately 0.4 micron) to beyond 2.5 microns. There are a few small broad absorption bands between 2.3 and 2.5 microns of approximately 2-5 percent. No change in color was noted upon baking the lenses at + 65°C for approximately one week total time. (1) Turini determined the spectral transmission of 0.001 in. layer of Eccogel 1265. He found the transmission is flat between 0.4 to 2.5 microns, with no absorption bands.

- 
1. Emerson and Cuming, Vendor Literature
  2. Turini

## EPIKOTE 817

Chemical Type or Composition: Epoxide resin, thermosetting, two-component system

Manufacturer: Shell Chemical Company, Ltd.

### PROCESSING DATA

Cure Times: 60°C for 6 hours or 80°C for 3 hours

Decementing: Castor oil at 280 - 300°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 300 lbf/in<sup>2</sup> (2)

Shrinkage: 0.5 %

Weight Loss: Negligible

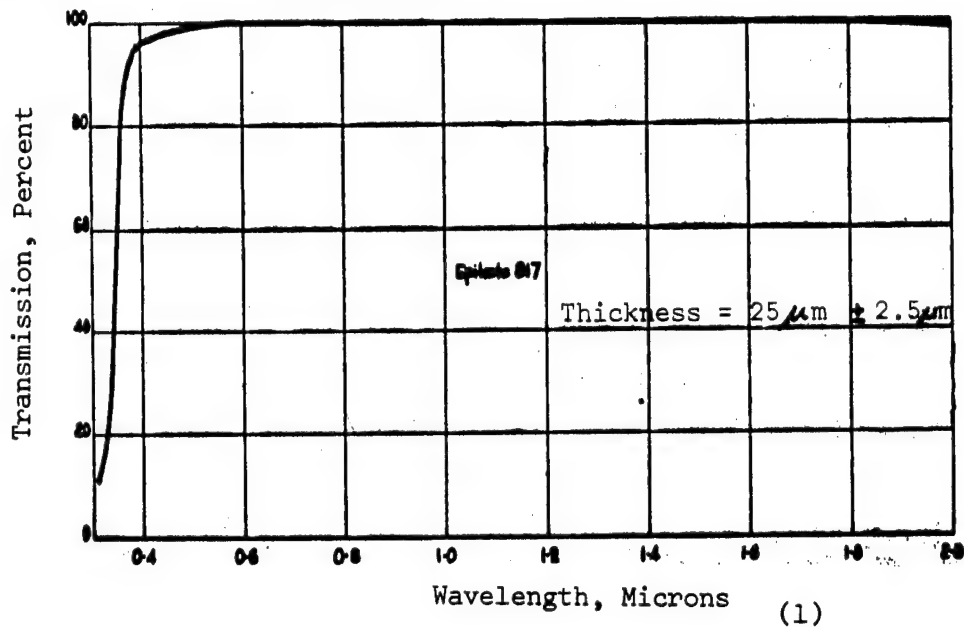
Linear Coefficient of Thermal Expansion:  $\alpha = 7.8 \times 10^{-5} / ^\circ\text{C}$

Thermal Shock Resistance: Unaffected by cycling at +70°C for two hours, -74°C for two hours, +70°C for two hours to room temperature.

### OPTICAL PROPERTIES

Refractive Index: 1.57

Clarity: Pale yellow



1. Hunt
2. Unit reported by Hunt



## EPOCAST 253 (FORMERLY 15 E)

Chemical Type or Composition: Epoxy, 2-component system - 100 parts Epocast 253 and 50 parts by weight of Hardener 9010

Manufacturer: Furane Plastics, Inc.

### PROCESSING DATA

Pot Life: one week at room temperature

Viscosity: At 25°C, 4000 centipoise (Brookfield)

Cure Times: 8-10 hours at 93°C plus 2 hours at 121°C or  
4 hours at 121°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 1100 psi (ASTM-D-638)

Hardness: At 25°C, 46/24 Shore D

Dielectric Strength: 400 volts/mil (ASTM D-149)

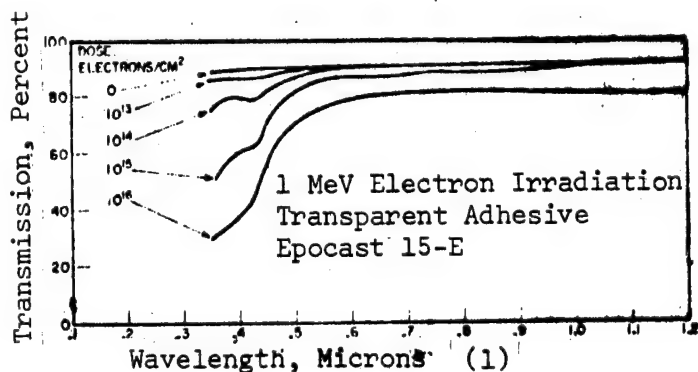
Dielectric Constant: 60 cps - 4.5,  $10^4$  cps - 4.2,  $10^6$  cps - 3.1 (ASTM D-150)

Dissipation Factor: 60 cps - 0.029,  $10^4$  cps - 0.030,  $10^6$  cps - 0.042 (ASTM D-150)

Volume Resistivity: At 25°C,  $2.9 \times 10^{14}$  ohm-cm, at 93°C,  $6.0 \times 10^{10}$  ohm-cm  
at 149°C,  $5.0 \times 10^9$  ohm-cm (ASTM D-257)

### OPTICAL PROPERTIES

Clarity: Clear



Exposure Equivalent to 630 hrs. of (1)  
Space UV

Material Designation	% Change in Transmittance at Wavelengths (microns)			
	0.5	0.6	0.7	0.8
15-E (Epocast)	43	31	27	25

Specimens are 1-2 mil thick films cast between sheets of fused silica, 30 mil base and 6 mil cover sheet with no cutoff filter to limit the UV reaching the specimen.

1. Campbell
2. Furane Vendor Literature

## EPOCAST H-1368/9313

Chemical Type or Composition: Epoxy, 2-component system, 100 parts by weight of H-1368 plus 34 parts by weight of 9313

Manufacturer: Furane Plastics, Inc.

### PROCESSING DATA

Pot Life: 90 minutes/100 grams

Viscosity: At 25°C, 4,000 centipoise

Cure Times: Overnight at room temperature plus 1 hour at 65°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 5,000 psi for a 1/2-inch thick sample

Hardness: 88 Shore D at 27°C for a 1/2-inch thick sample

Elongation: 10% for a 1/2-inch thick sample

Dielectric Constant: At  $10^4$  cps. - 5.7, at  $10^6$  cps. - 4.5

Dissipation Factor: At  $10^4$  cps. - 0.060, at  $10^6$  cps. - 0.076

Volume Resistivity: At 25°C,  $7 \times 10^{11}$  ohm-cm

Thermal Conductivity:  $4 \times 10^{-4}$  cal/cm<sup>2</sup>/sec/°C/cm

- 
1. Furane Plastics, Inc. Vendor Literature
  2. Evaluation of Organic Resins for Space Environment

# EFFECT OF UV EXPOSURE OF EPOCAST H-1368 (2)

EXPOSURE	PERCENT TRANSMISSION									
	200 mμ		300 mμ		400 mμ		500 mμ		700 mμ	
	Before	After	Before	After	Before	After	Before	After	Before	After
Nominal *	0	0	35.0	0	91.0	6.5	91.5	32.0	94.0	58.0
Sun Intensity										
of 6-										
Nominal *	0	0	63.0	0	87.0	0	88.5	5.5	92.0	44.0
Sun Intensity										
of 20										

\* Exposure 97.7 hours at  $1 \times 10^{-6}$  torr.

## 2. Evaluation of Organic Resins for Space Environment.

## EPO-TEK 301

Chemical Type or Composition: Epoxy, two-component system

Manufacturer: Epoxy Technology, Inc.

### PROCESSING DATA

Pot Life: 50 minutes/ 25 gms or 30 minutes/ 100 gms

Viscosity: 100 centipoise

Cure Times: Overnight at room temperature or one hour at 65°C

Service Temperature: Pyrex and EDF-4 joined with EPO-TEK 301 failed at -40°C. Cement thickness ranged from 0.003 to 0.0003 in. (2)

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Weight Loss: 1.08 % after curing for 24 hours at room temperature and tested in a vacuum of  $10^{-6}$  Torr. No volatile condensable material released. (1)

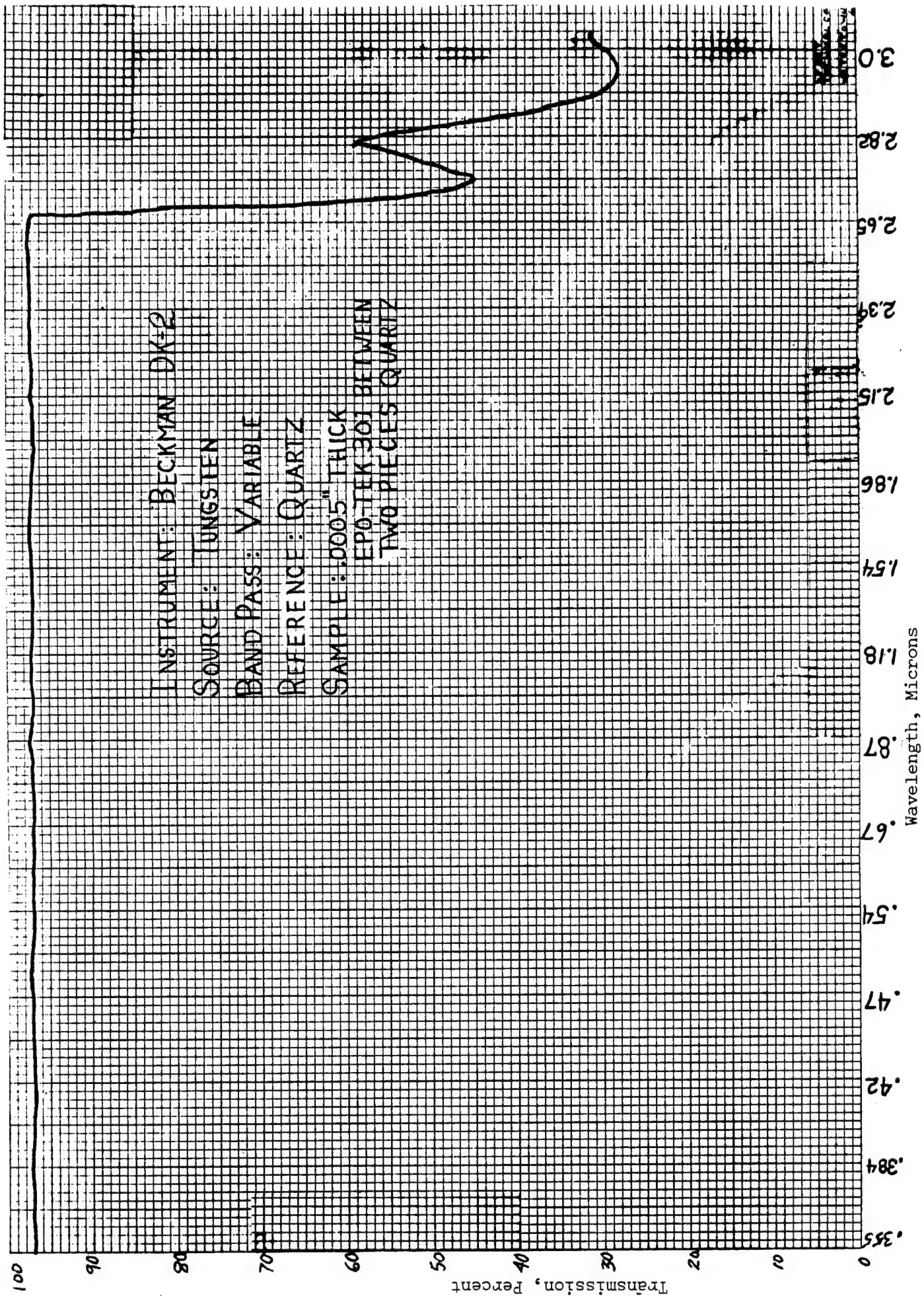
### OPTICAL PROPERTIES

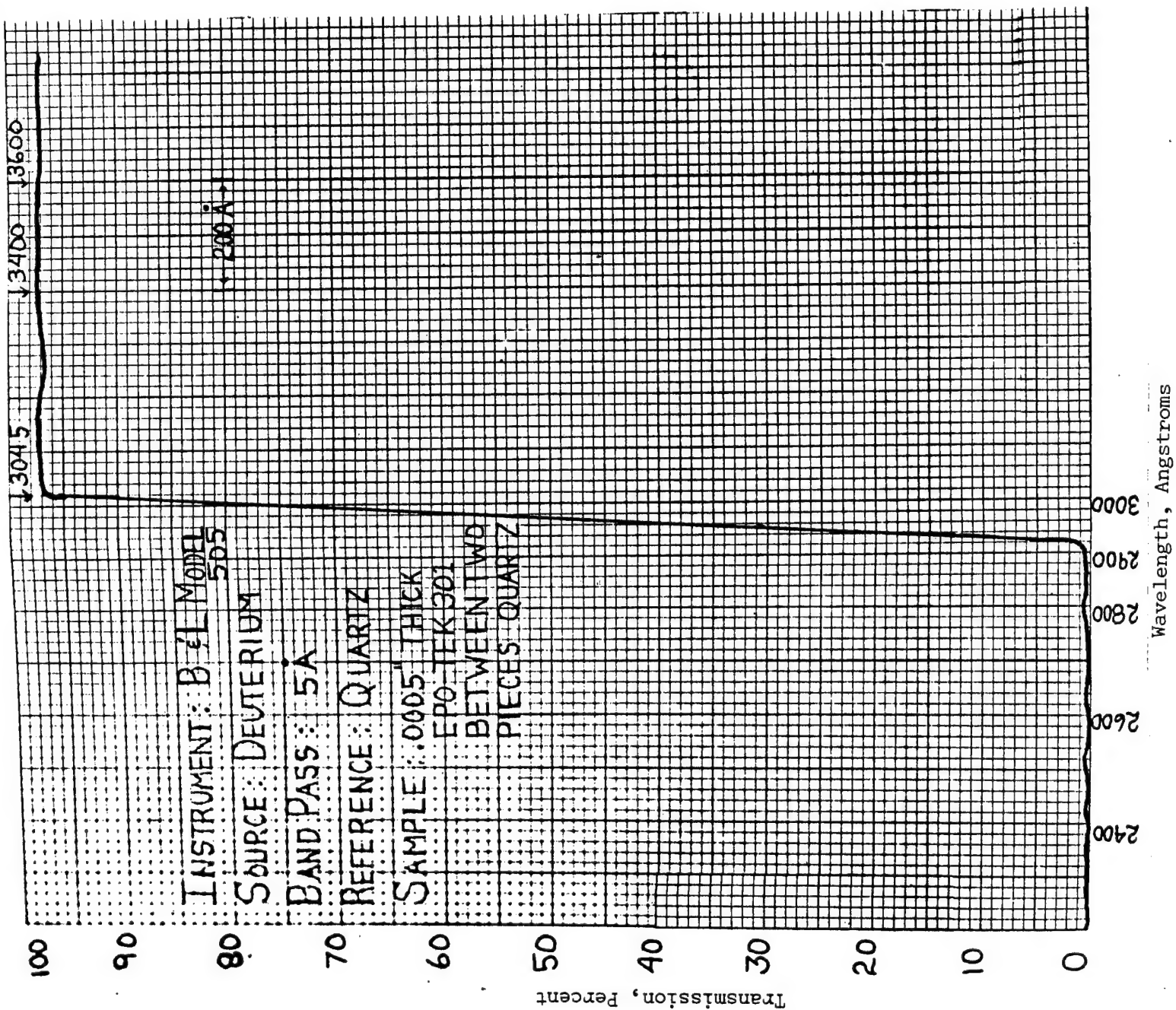
Refractive Index: 1.538 to 1.540

Clarity: Clear

Light Transmission: Optically Transparent from 3,000 Å to 2.6  $\mu$  (1)

- 
1. Epoxy Technology, Inc., Vendor Literature
  2. Turini





## EPO-TEK 305

Chemical Type or Composition: Epoxy, two-component

Manufacturer: Epoxy Technology Inc.

### PROCESSING DATA

Pot Life: 20 minutes per 10 gm.

Cure Times: Overnight at room temperature or 30 minutes at 65°C

### OPTICAL PROPERTIES

Refractive Index: 1.5110

Light Transmission:

60 % at 2200 Å

85 % at 2500 Å

94 % at 2600 Å to 2.6 microns

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Epoxy Technology Inc., Vendor Literature

## EPOXY - 20 ADHESIVE

Chemical Type or Composition: Crossed polymer of bisphenol poly-glycol epoxide, two-component system.

Manufacturer: Transene Company

### PROCESSING DATA

Shelf Life: 6 months

Pot Life: 4 hours

Cure Times: 5 hours at 70°C or 4 days at room temperature.

Service Temperature: Used for solar cell applications.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Lap Shear Strength: 1,200 psi

Hardness: 75 Shore D Durometer

Dielectric Constant: At 1 Mc - 3.3

Dissipation Factor: At 1 Mc - 0.032

Volume Resistivity:  $10^{15}$  ohm-cm

### OPTICAL PROPERTIES

Clarity: Clear - high light transmission

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1. Transene Company, Inc., Vendor Literature

Chemical Type or Composition: Polyvinyl Acetate

Manufacturer: Monsanto Company

#### PROCESSING DATA

Decementing: Dry heat at 100°C

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 20°C, 1.19

Tensile Strength: Less than 300 lbf/in.<sup>2</sup> (3)

Dielectric Strength: 1,000 volt/mil

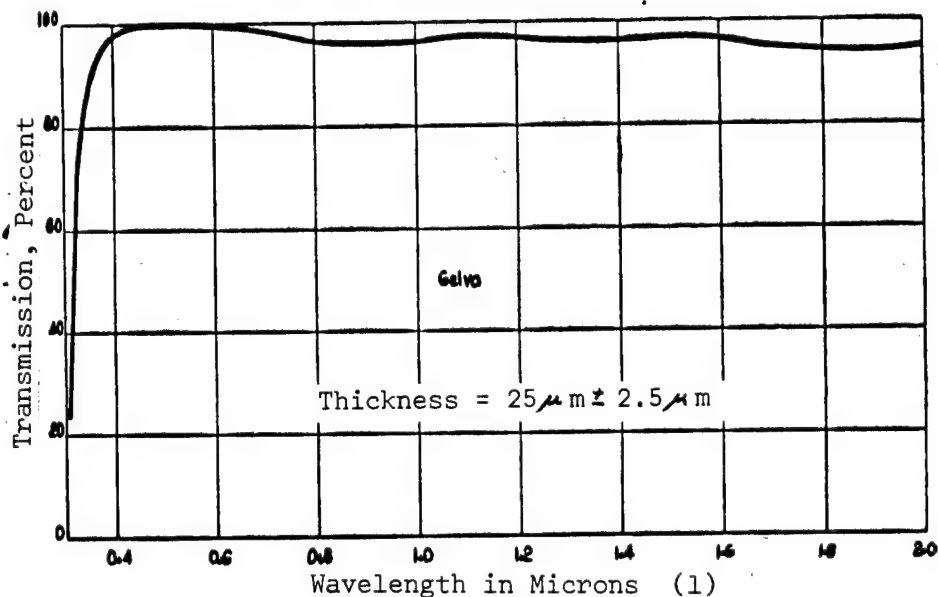
Dielectric Constant: At 30°C, 2.7 1 MHz (2)

Coefficient of Thermal Expansion:  $8.6 \times 10^{-5}/^{\circ}\text{C}$

Thermal Shock Resistance: Bubbles appear after cycling at +70°C for 2 hours, -74°C for 2 hours, +70°C for 2 hours, then to room temperature.

#### OPTICAL PROPERTIES

Refractive Index: 1.48



1. Hunt
2. Smith
3. Unit reported by Hunt



## GLYCERINE

Manufacturer: Dow Chemical Co., Merck and Company, Inc. and Swift and Company

### PROCESSING DATA

Viscosity: At 20°C, 1,499 centipoises (1)  
At 25°C, 945 centipoises  
At 30°C, 624 centipoises

Boiling Point: 290°C (2)  
Melting Point: 20.0°C (2), 17.9°C for 99.5% glycerine (5)  
Surface Tension: At 18°C, 63 Dynes/cm (1)

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.262 (5)

Dielectric Constant: At 20°C, 43 (3)

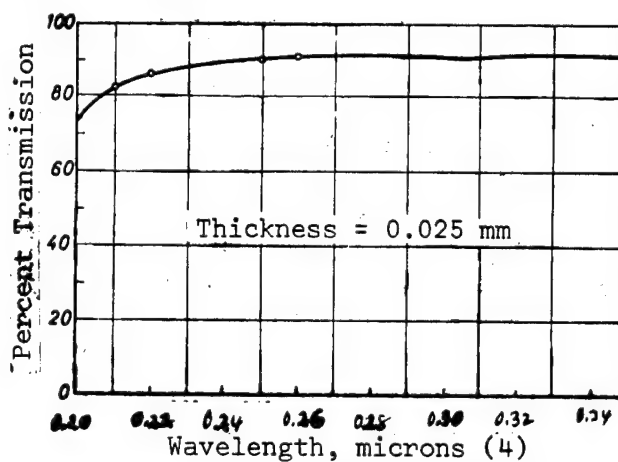
Thermal Conductivity: At 25°C,  $6.8 \times 10^{-4}$  cal/cm-sec °C (1)  
Coefficient of Cubical Expansion: At 20°C,  $5.05 \times 10^{-4}$  /°C (1)  
Specific Heat: At 15 - 50°C, 0.57 cal/g°C (1)

### OPTICAL PROPERTIES

Refractive Index: At 25°C, 1.472 (U.S.P. 99.5%) (5)

0.434	0.496	0.589	0.656	(1)
1.4828	1.4784	1.4730	1.4706	

Clarity: Colorless liquid



1. Forsythe
2. Weast
3. Kaye
4. Pellicori
5. Dow Chemical Company, Vendor Literature

Chemical Type or Composition: Methacrylate, semi-thermosetting

Manufacturer: Eastman Kodak Company

PROCESSING DATA

Shelf Life: 1 month refrigerated, storage at 2-6°C

Viscosity: 1000 to 1500 centipoise

Cure Times: 16 hours at 70°C on 7 hours at 82°C

Service Temperature: -46 to 82°C

Decementing: Xylene immersion: decementing action increased by heating  
in xylene to 70°C. Separation time 6 hours. Solvents: acetone  
or toluene.

MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

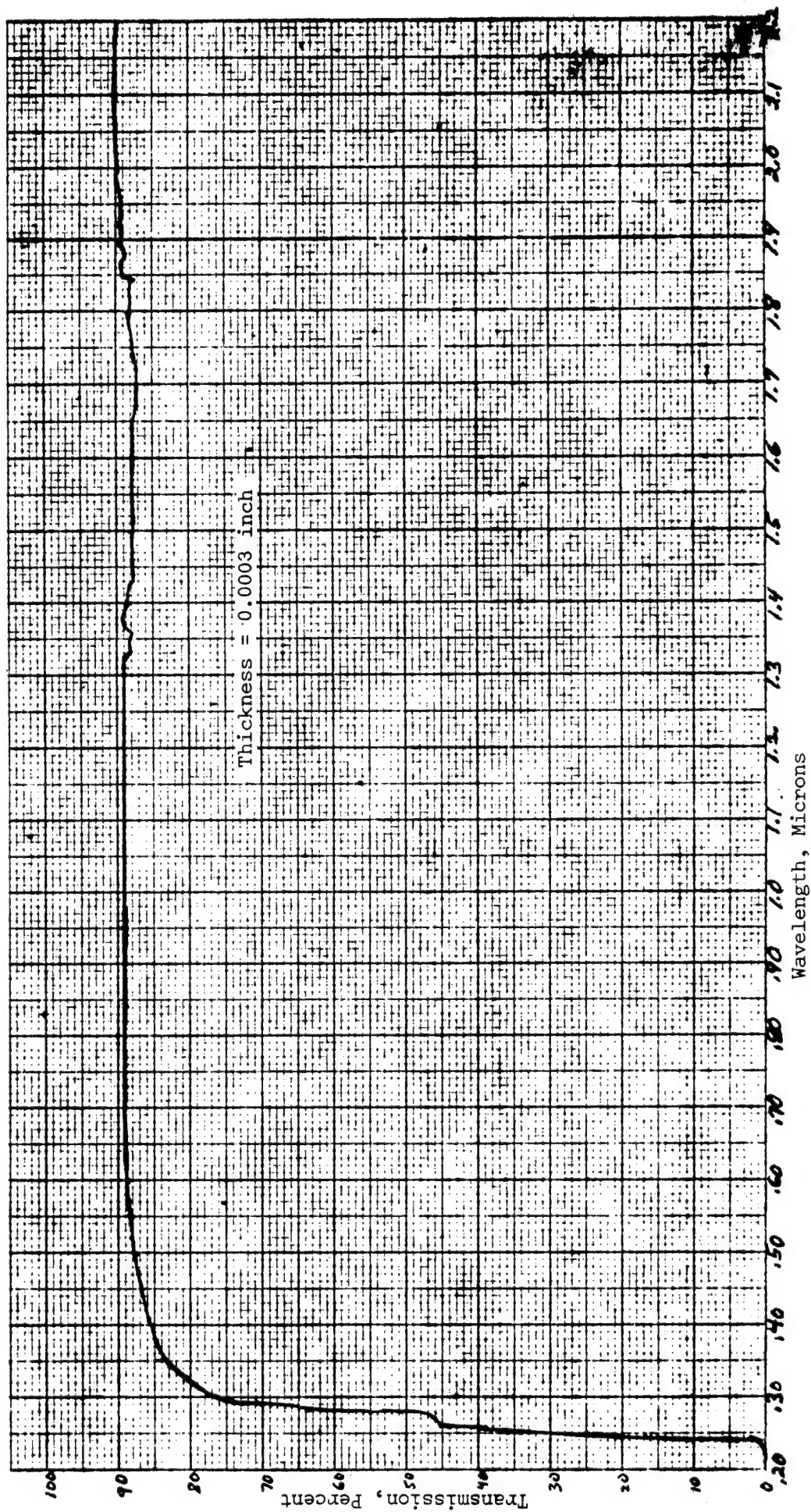
Shrinkage: Factor ~ 18%

OPTICAL PROPERTIES

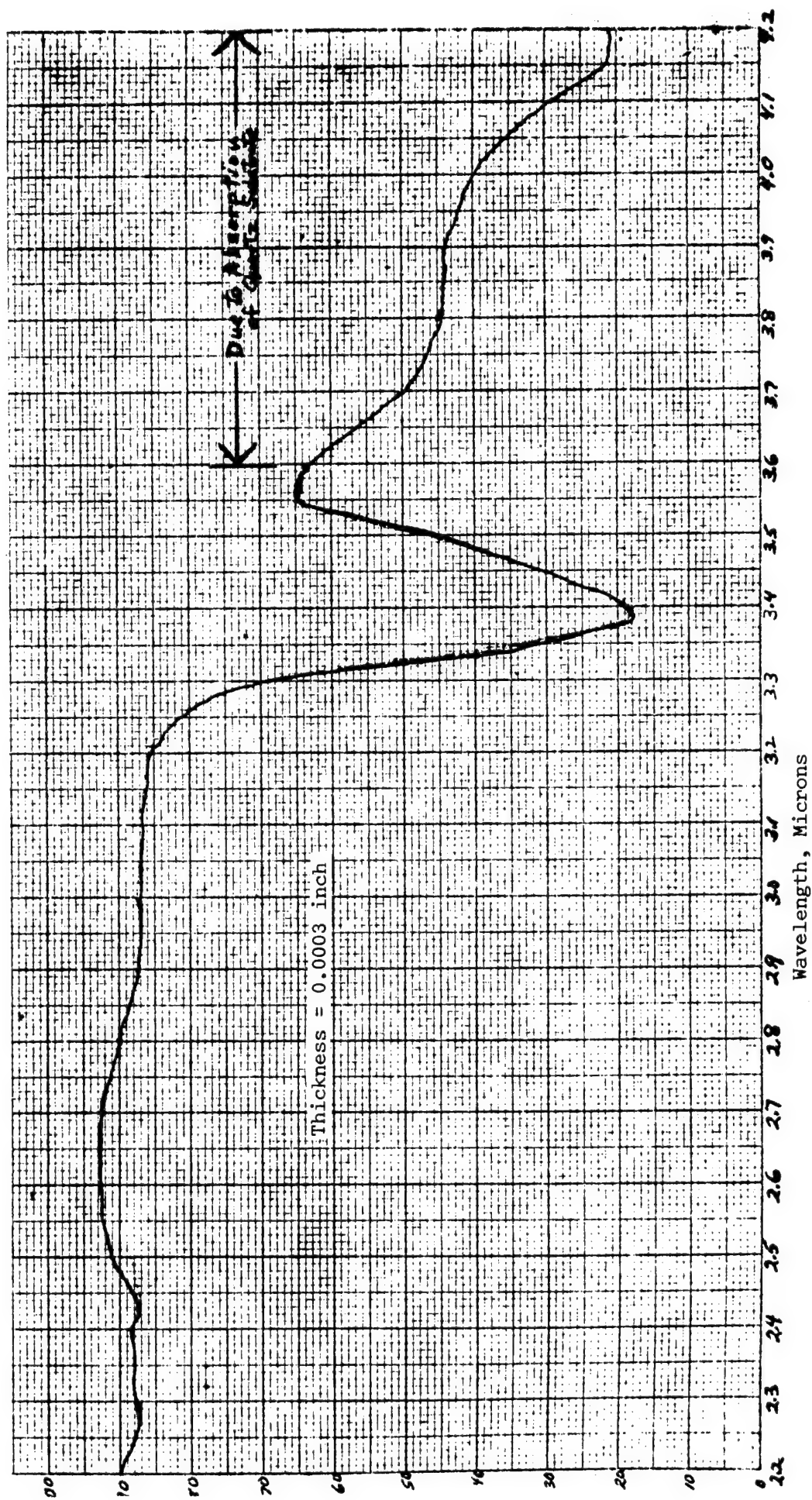
Refractive Index: 1.48

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Eastman Kodak Company - used for all types of lens and prism assemblies.



GE 106 Quartz Sandwich with HE-2 (Eastman Kodak Co.)



GE 106 Quartz Sandwich with HE-2 (Eastman Kodak Co.)

## HE-10

Chemical Type or Composition: Epoxy, two-component  
Manufacturer: Eastman Kodak Company

### PROCESSING DATA

Shelf Life: 1 year  
Viscosity: 1000 to 1500 centipoise  
Cure Times: 48 hours at room temperature, 8 hours at 50°C or 4 hours at 71°C.  
Must be vacuum degassed before use.  
Service Temperature: -54 to 85°C. Pyrex and EDF-4 glass joined with  
HE 10 for a lens system application failed between -40  
and -50°C. (2)  
Decementing: Soaking or boiling in chlorinated hydrocarbon or heat to 150°C  
and slide apart. May be decemented by boiling in Summers  
Laboratories RD 3-74. Solvent acetone or alcohol.

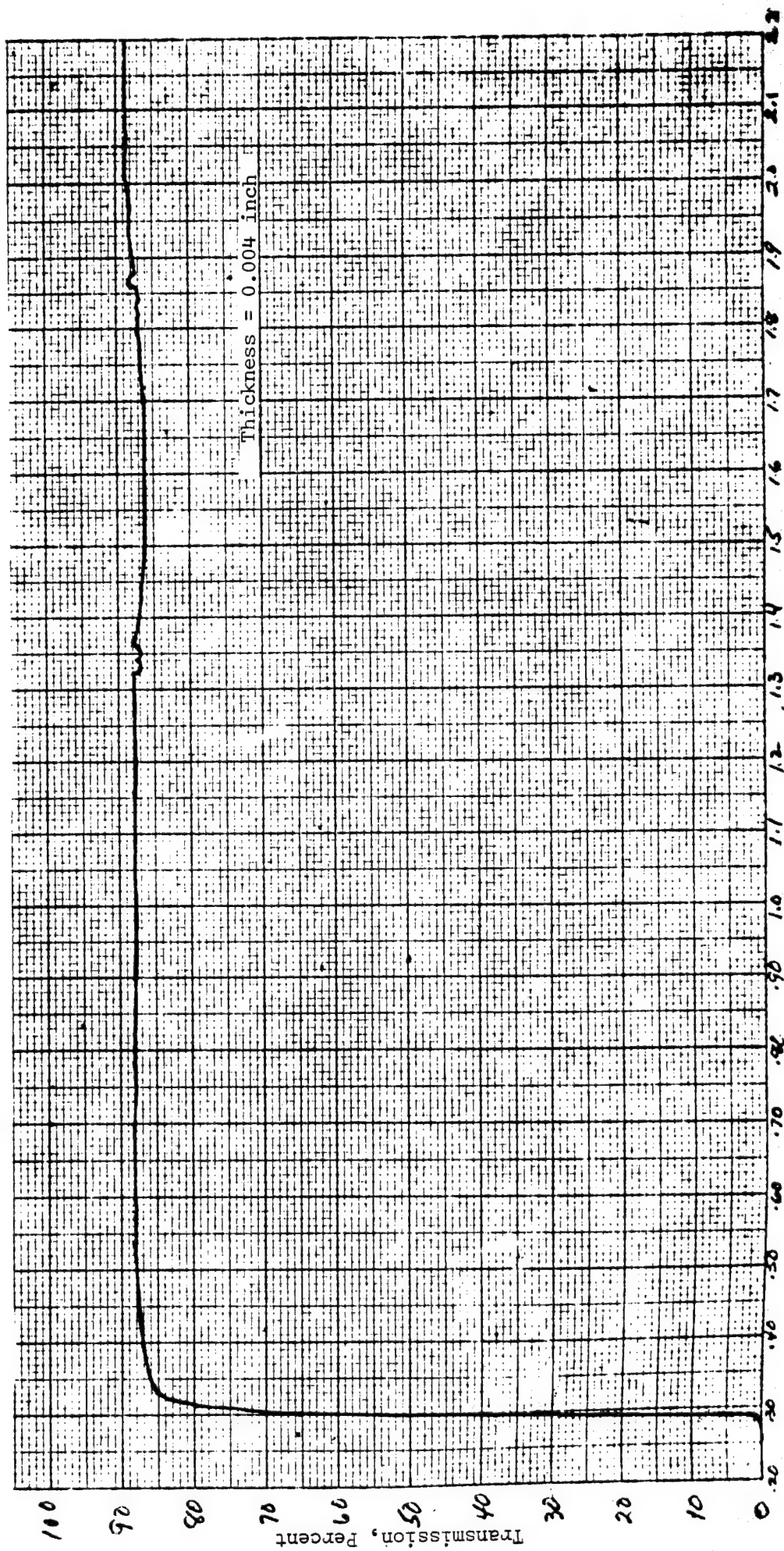
### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage: Factor ~ 4%

### OPTICAL PROPERTIES

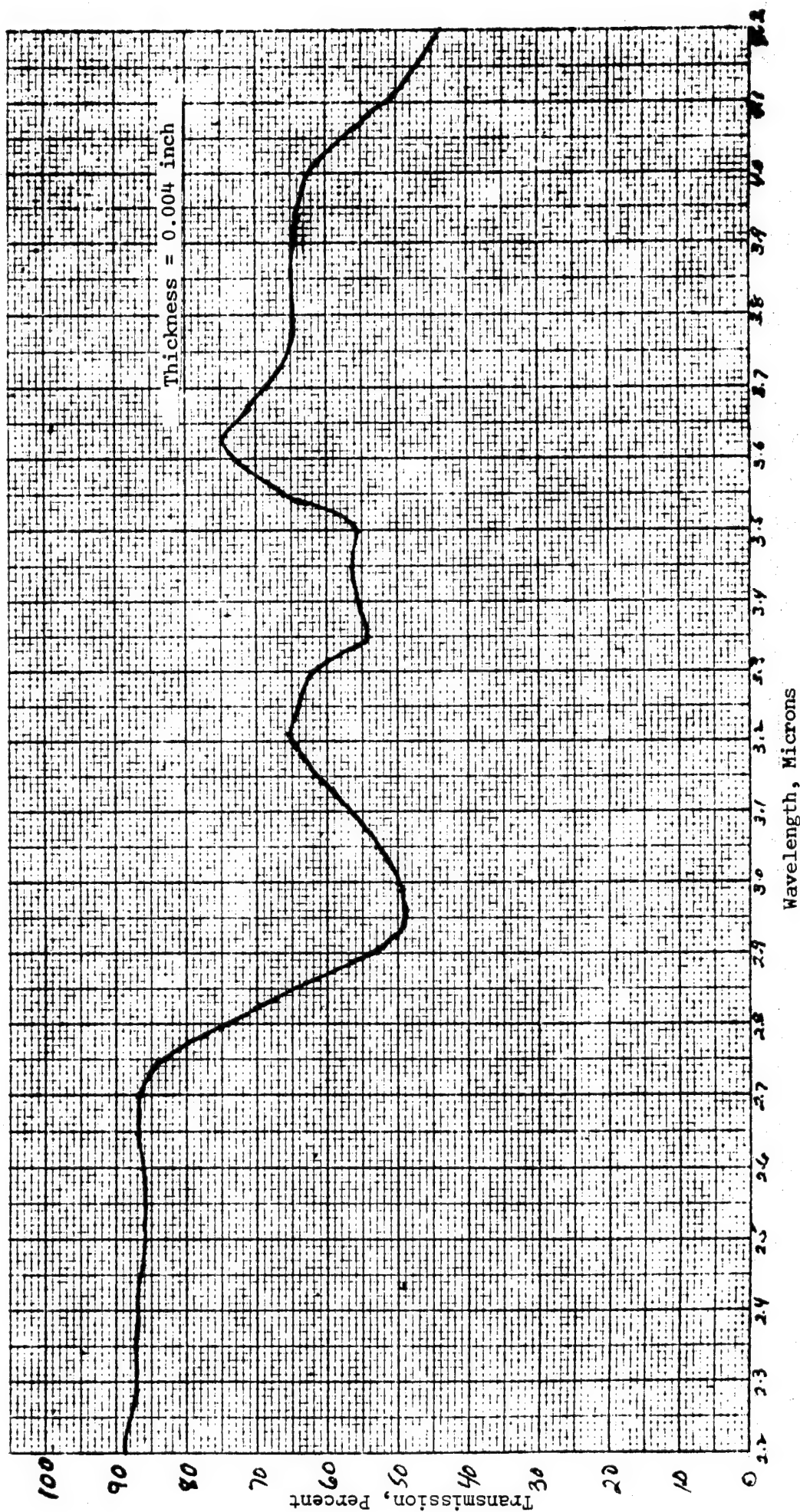
Refractive Index: 1.577

- 
1. Eastman Kodak Vendor Literature
  2. Turini



Wavelength, Microns  
GE 106 Quartz Sandwich with HE-10 (1)





Wavelength, Microns

GE 106 Quartz Sandwich with HE-10 (1)

Note: The reduction in transmission from 3.6 microns to 4.2 microns may be due to absorption of the Quartz Substrate as indicated on the curve for HE-63.

## HE-63

Chemical Type and Composition: Thermosetting

Manufacturer: Eastman Kodak Company

### PROCESSING DATA

Shelf Life: 3 months refrigerated, storage at 2-6°C

Viscosity of Uncured Adhesive: 1000 to 1500 centipoise

Cure Times: 40 hours at 70°C

Service Temperature: -65 to 86°C. Can withstand 90% relative humidity at 54°C for 1 week

Decementing: Shocking in Wesson Oil at 150 to 205°C. Delicate lenses soaked in chloroform at 50°C for several days. Solvent Acetone or alcohol.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

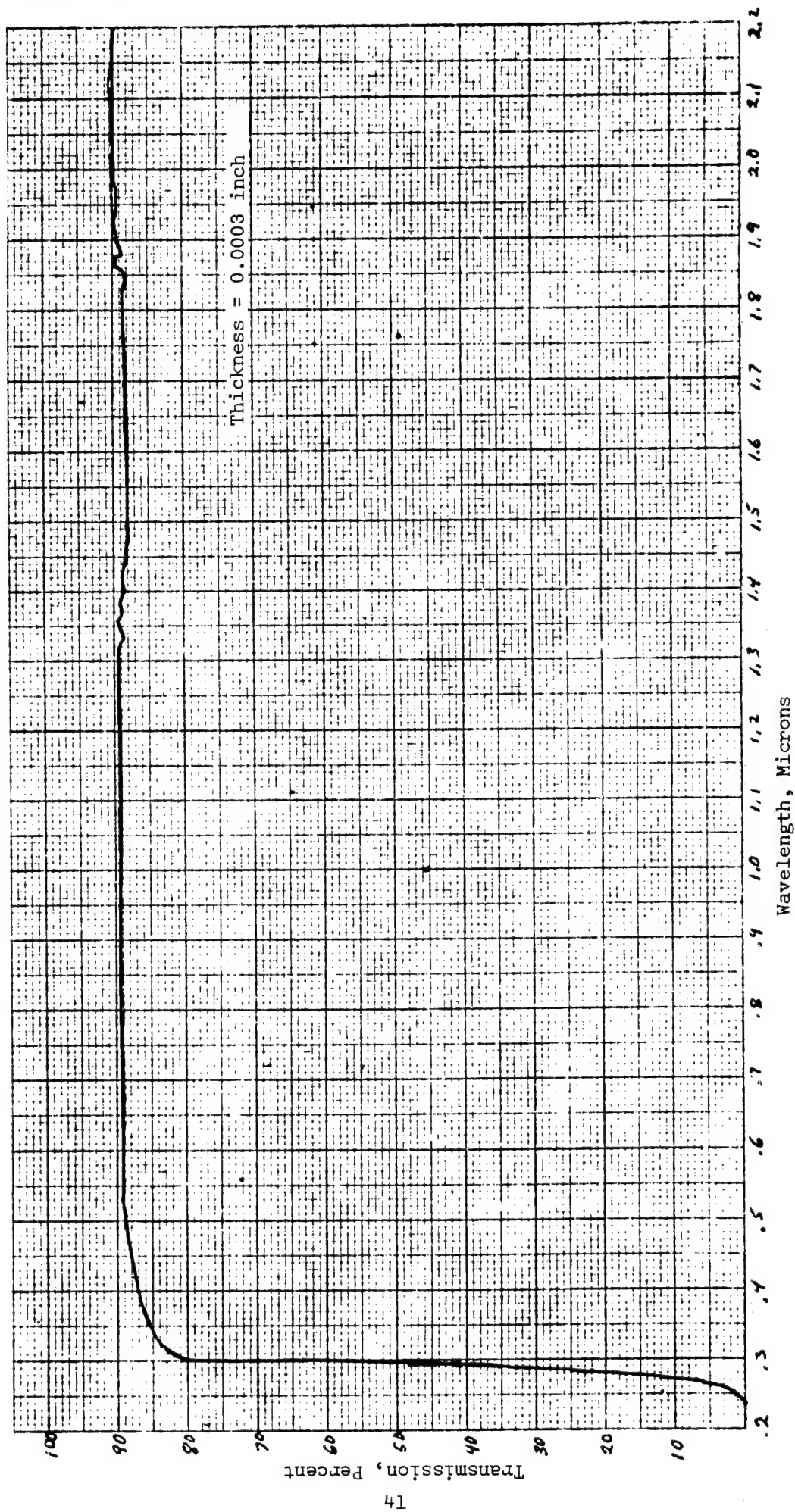
Shrinkage: Factor ~ 9%

### OPTICAL PROPERTIES

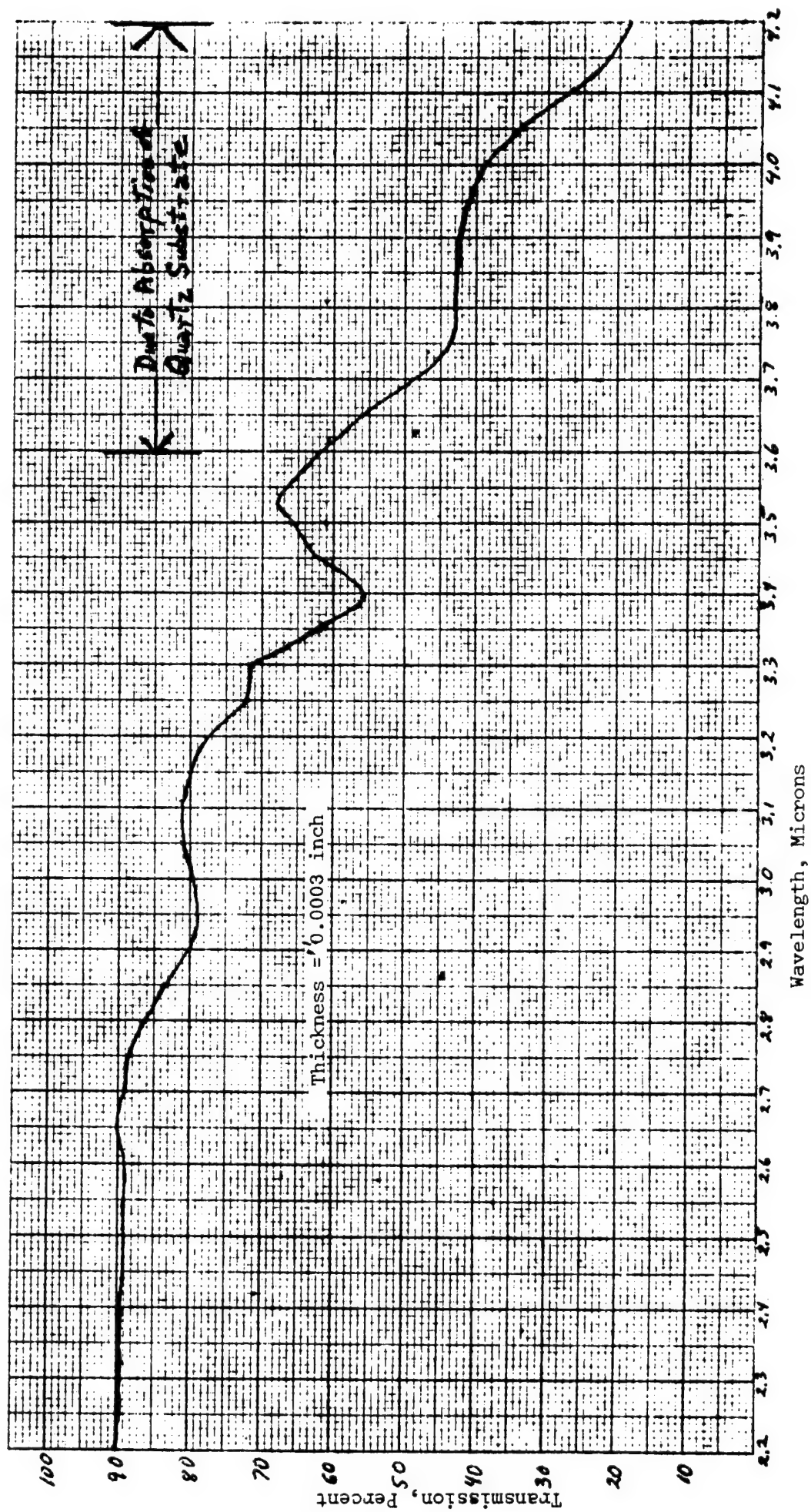
Refractive Index: 1.576

- 
1. Eastman Kodak Vendor Literature





GE 106 Quartz Sandwich with HE-63 (1)



GE 106 Quartz Sandwich with HE-63 (1)

## HE-65

Chemical Type or Composition: Thermosetting

Manufacturer: Eastman Kodak Company

### PROCESSING DATA

Shelf Life: 2 months refrigerated, storage at 2-6°C

Viscosity: 3000 to 6000 centipoise

Cure Times: 40 hours at 70°C

Service Temperature: -65 to 86°C, designed to withstand 90% humidity at 54°C for 1 week.

Decementing: Lens elements can be decemented by shocking in Wesson Oil (or equivalent) at 150 to 205°C. If the lens is too large to stand that much shock, preheat it. Several minutes will be required for separation to occur. Delicate lenses may be decemented by soaking chloroform, at approximately 50°C, for several days. Solvent alcohol or acetone.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage: Factor ~ 9%

### OPTICAL PROPERTIES

Refractive Index: 1.576

---

Eastmak Kodak Vendor Literature - used for lens and prism assemblies.

HE-79

MIL-A-003920 A (ORD)

Chemical Type or Composition: Styrene Modified Polyester (1) Meets MIL-A-003920 A (ORD)

Manufacturer: Eastman Kodak Company

### PROCESSING DATA

Shelf Life: 1 to 2 years

Viscosity: 400 centipoise

Cure Times: 1 week at room temperature, overnight at 50°C or 3 hours at 70°C.

Service Temperature: -65 to 85°C depending on size and shape of optical system.

Decementing: Solvent acetone or toluene. Shock in Wesson Oil at 150 to 205°C or soak in chloroform at 50°C for several days.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage: Factor ~ 9%

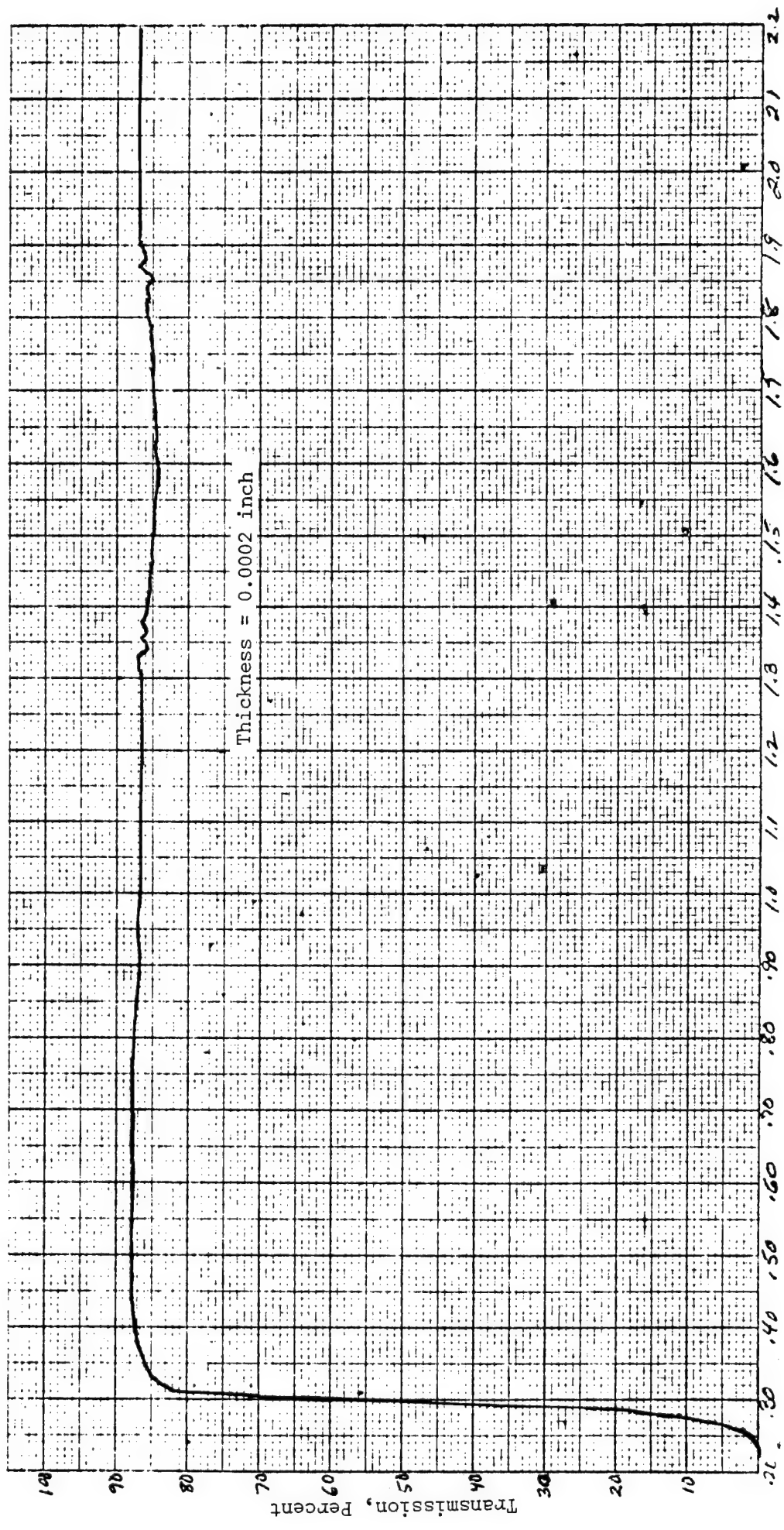
### OPTICAL PROPERTIES

Refractive Index: 1.567

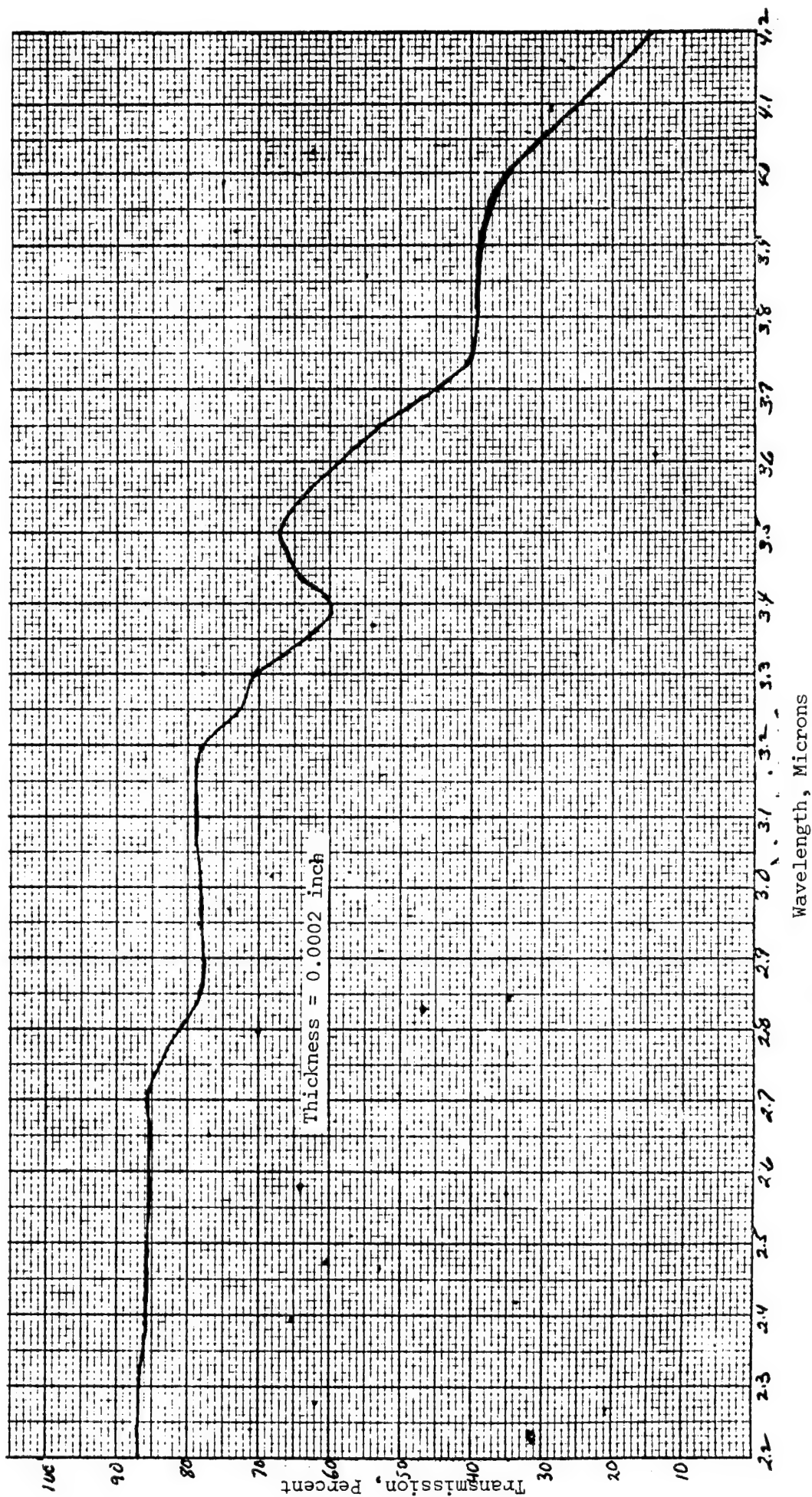
---

1. Katz

2. Eastman Kodak Company - used for glass optical cementing.



GE 106 Quartz Sandwich with HE-79 (2)



Wavelength, Microns

GE 106 Quartz Sandwich with HE-79 (2)

Note: The reduction in transmission after 3.6 microns may be due to absorption of the quartz substrate as indicated for HE-63.



HE-100 B

Chemical Type or Composition: Thermoplastic

Manufacturer: Eastman Kodak Company

PROCESSING DATA

Shelf Life: 1 year

Viscosity: 1500 centipoise

Cure Times: 2 days at room temperature or 16 hours at 70°C

Service Temperature: -35 to 85°C

Decementing: Solvent acetone, xylene or trichloroethylene

MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage: Factor ~ 70%

OPTICAL PROPERTIES

Refractive Index: 1.48

---

Eastman Kodak Vendor Literature - used as an assembly cement - general purpose adhesive. Fast drying.

HE-100 X

Chemical Type or Composition: Thermoplastic

Manufacturer: Eastman Kodak Company

PROCESSING DATA

Shelf Life: 1 year

Viscosity: 1000 centipoise

Cure Times: 4 days at room temperature or 16 hours at 70°C.

Service Temperature: -35 to 85°C

Decementing: Solvent acetone, xylene or trichloroethylene

MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage: Factor ~ 70%

OPTICAL PROPERTIES

Refractive Index: 1.48

---

Eastman Kodak Vendor Literature - used as assembly cement - general purpose adhesive.

#### HE-F-4

Chemical Type or Composition: Butyl methacrylate

Manufacturer: Eastman Kodak Company

#### PROCESSING DATA

Shelf Life: 1 month refrigerated storage

Viscosity: 1000 to 1500 centipoise

Cure Times: 40 hours at 50°C.

Service Temperature: -65 to 70°C

Decementing: Heat lens to 150 to 177°C on a covered hot plate or in an oven.  
They can also be separated by immersion in xylene at 50°C for  
a time commensurate with their size.

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Shrinkage Factor: 15%

#### OPTICAL PROPERTIES

Refractive Index: 1.49

- 
1. Eastman Kodak Vendor Literature - used as an optical cement, gelatin filter between glass and many types of optical assemblies.

## H.T. CEMENT

Chemical Type or Composition: Partially polymerized n-butyl methacrylate, a catalyst and an inhibitor. Thermosetting

Manufacturer: Hopkin & Williams Division of Baird & Tatlock, Ltd.

### PROCESSING DATA

Shelf Life: Storage in a dark cool place. (1)

Cure Times: 5 hours at 75°C or 16 hours at 60°C (1)

Decementing: Dry heat at 100°C (2)

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 300 lbf/in<sup>2</sup> (2)

Shrinkage: 11.5 % (2)

Weight Loss: 5.9 % (3)

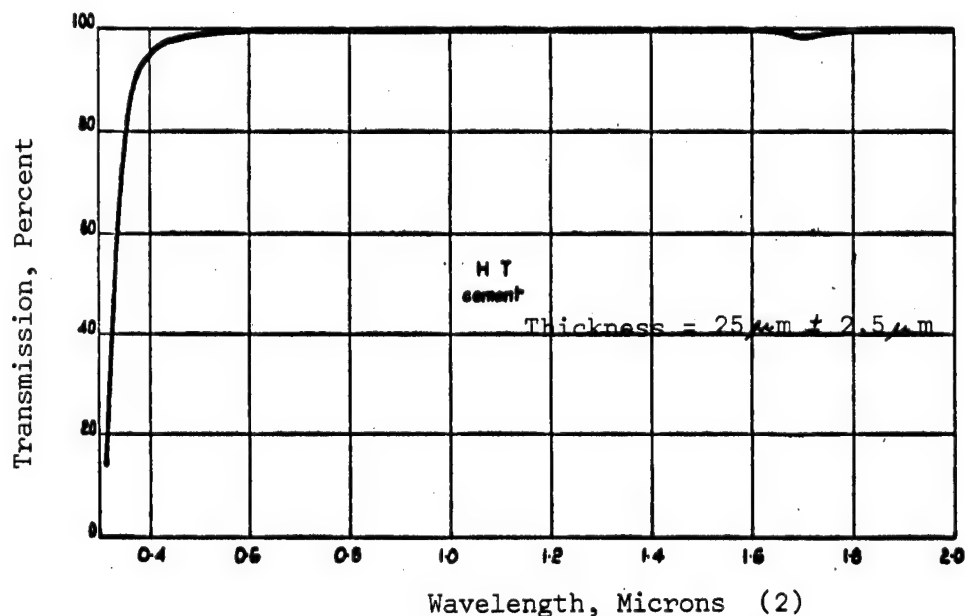
Thermal Shock Resistance: Bubbles produced after cycling at 70°C for 2 hours, -74°C for 1/2 hour, 70°C for 2 hours to room temperature. (2)

### OPTICAL PROPERTIES

Refractive Index: 1.45 (2)

1.491 (3)

Clarity: Water-white to pale yellow



1. Hopkin & Williams Division of Baird & Tatlock, Ltd., Vendor Literature
2. Hunt. Hunt's units are reported.
3. Kaye



## LENS BOND TYPE C-59

Chemical Type or Composition: Styrene monomer and unsaturated polyester, thermosetting, on qualified products list for military specification MIL-A-003920A(ORD) for MI-10-2A cement. Two components.

Manufacturer: Summers Laboratories, Inc.

### PROCESSING DATA

Shelf Life: 18 months

Viscosity: 300 centipoise

Cure Times: Precures in 2 days at room temperature or 45 minutes at 70°C. Full cure at 6 days at room temperature or 2 hours at 70°C.

Service Temperature: -54°C to 100°C. A special formulation C-59, RD-374 was used to bond pyrex and plate glass. The cement failed between 0 and 15°C. The cement withstood +65°C with no noticeable change. (2)

Decementing: Use Summers Laboratories, Inc. solvent

### MECHANICAL, ELECTRONIC, AND THERMAL PROPERTIES

Specific Gravity: 1.22

Tensile Strength: 10,000 psi

Shrinkage in Cure: 6.8 %

Dielectric Constant: 3 at  $10^6$  cps

Dissipation Factor: .05 at  $10^6$  cps

### OPTICAL PROPERTIES

Refractive Index Cured: 1.55

Light Transmission: 100% from 10,000 Å to 4,000 Å  
99% 3,500 Å  
96% 3,000 Å  
90% 2,900 Å

- 
1. Summers Vendor Literature
  2. Turini

## LENS BOND TYPE F-65

**Chemical Type or Composition:** Styrene monomer and unsaturated polyester thermosetting, two-component

**Manufacturer:** Summers Laboratories, Inc.

### PROCESSING DATA

**Shelf Life:** 18 months

**Viscosity:** 300 centipoise

**Cure Times:** Pre-cure in 1/2 hour at room temperature. Full cure in 1 day

**Service Temperature:** -54°C to 100°C

**Decementing:** Summers Laboratories RD 3-74

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

**Specific Gravity:** 1.22

**Tensile Strength:** 10,000 psi

**Shrinkage in Cure:** 6.8%

**Dielectric Constant:** 3 at  $10^6$  cps

**Dissipation Factor:** .05 at  $10^6$  cps

### OPTICAL PROPERTIES

**Refractive Index Cured:** 1.55

**Light Transmission:** 100% from 5,000 Å to 10,000 Å

99% 4,000 Å

97% 3,500 Å

94% 3,000 Å

84% 2,900 Å

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Summers Vendor Literature

## LENS BOND TYPE M-62

**Chemical Type or Composition:** Styrene monomer and unsaturated polyester  
thermosetting, two-component

**Manufacturer:** Summers Laboratories, Inc.

### PROCESSING DATA

**Shelf Life:** 18 months

**Viscosity:** 300 centipoise

**Cure Times:** Pre-cure in 4 hours at room temperature or 20 minutes at 70°C.  
Full cure in 4 additional days at room temperature or 1 hour at 70°C.

**Service Temperature:** -54°C to 100°C

**Decementing:** Summers Laboratories RD 3-74

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

**Specific Gravity:** 1.22

**Tensile Strength:** 10,000 psi

**Shrinkage in Cure:** 6.8%

**Dielectric Constant:** 3 at  $10^6$  cps

**Dissipation Factor:** .05 at  $10^6$  cps

### OPTICAL PROPERTIES

**Refractive Index Cured:** 1.55

**Light Transmission:** 100% from 4,000 Å to 10,000 Å  
99% 3,500 Å  
96% 3,000 Å  
90% 2,900 Å

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Summers Vendor Literature

## LENS BOND TYPE U-69

**Chemical Type or Composition:** Styrene monomer and unsaturated polyester, one-component

**Manufacturer:** Summers Laboratories, Inc.

### PROCESSING DATA

**Shelf Life:** 18 months  
**Viscosity:** 300 centipoise  
**Cure Times:** Cures with ultraviolet light. Pre-cure in 2 to 10 minutes depending on lens thickness. Full cure 10 times pre-cure period.  
**Service Temperature:** -54°C to 100°C  
**Decementing:** Summers Laboratories RD 3-74

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

**Specific Gravity:** 1.22  
**Tensile Strength:** 10,000 psi  
**Shrinkage in Cure:** 6.8%  
**Dielectric Constant:** 3 at  $10^6$  cps  
**Dissipation Factor:** .05 at  $10^6$  cps

### OPTICAL PROPERTIES

**Refractive Index Cured:** 1.55  
**Light Transmission:** 100% from 5,000 Å to 10,000 Å  
99% 4,000 Å  
96% 3,500 Å  
90% 3,000 Å  
82% 2,900 Å

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Summers Vendor Literature

## OPTICON SFA-23

Chemical Type or Composition: Epoxy, two-or three-component system

Manufacturer: Opticon Chemical Division of Dynalysis, Inc.

### PROCESSING DATA

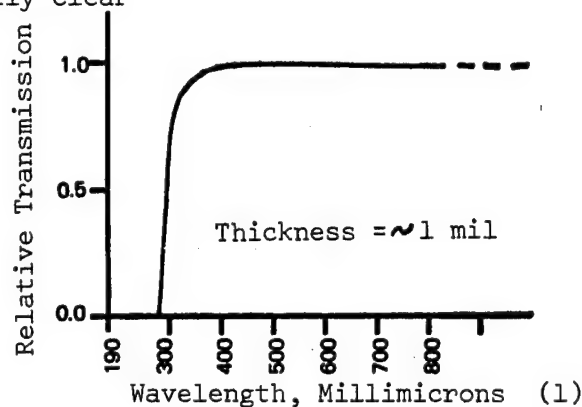
Shelf Life: Four months when stored at 5°C or below  
Cure Times: With two drops of accelerator and two drops of cement setting time at room temperature is five seconds. With ten drops of accelerator, eighty drops of moderator and two drops of cement, setting time is 70 minutes at room temperature.  
Decementing: Lenses which have been heated or which have high concentrations of accelerator may require epoxy strippers and heat. Parts having high concentrations of modifier can generally be removed by soaking in acetone for 16 hours at room temperature.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Thermal Shock Resistance: Three cycles of 110°C to -78°C with 15 minute dwell at each temperature extreme.

### OPTICAL PROPERTIES

Clarity: Optically Clear



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1. Opticon Chemical, Vendor Literature

## OPTICON UV-57

Chemical Type or Composition: Photosensitive synthetic resin

Manufacturer: Opticon Chemical Division of Dynalysis, Inc.

### PROCESSING DATA

Shelf Life: Four months at 5°C. At 25°C shelf life is two to three weeks.

Cure Times: Sets in 5 minutes when exposed to ultraviolet radiation. UV-57 may also be cured by using a catalyst instead of ultraviolet radiation.

Decementing: Soaking in acetone and gently prying apart.

Service Temperature: -54°C to 93°C with short exposures to 177°C.

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 25°C, 1.12

Viscosity: At 25°C, 830 centipoise (Spindle 3, 60 rpm)

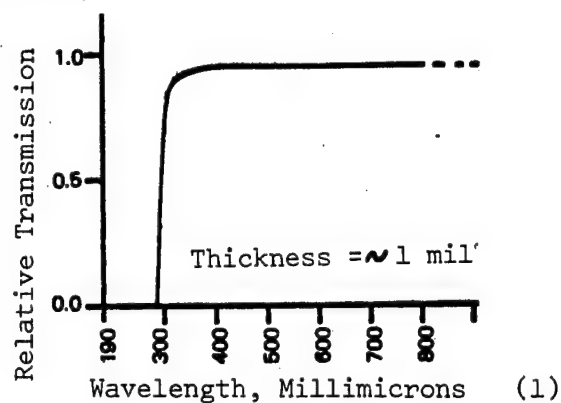
Thermal Shock Resistance: No damage when shocked from -54°C and cycled to 93°C.

### OPTICAL PROPERTIES

Refractive Index: 1.5316

Clarity: Optically clear, colorless

Light Transmission: 93 %



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1. Opticon Chemical, Vendor Literature

## ROSS OPTICAL CEMENT No. 24

Chemical Type or Composition: Proprietary mixture of n-butyl methacrylate catalyst, inhibitor and canada balsam. Thermosetting.

Manufacturer: Ross Ltd.

### PROCESSING DATA

Cure Times: 36 hours at 80°C

Decementing: Dry heat at 100°C or heating in toluene or xylene

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Tensile Strength: 300 lbf/in.<sup>2</sup> (2)

Shrinkage: 9.5%

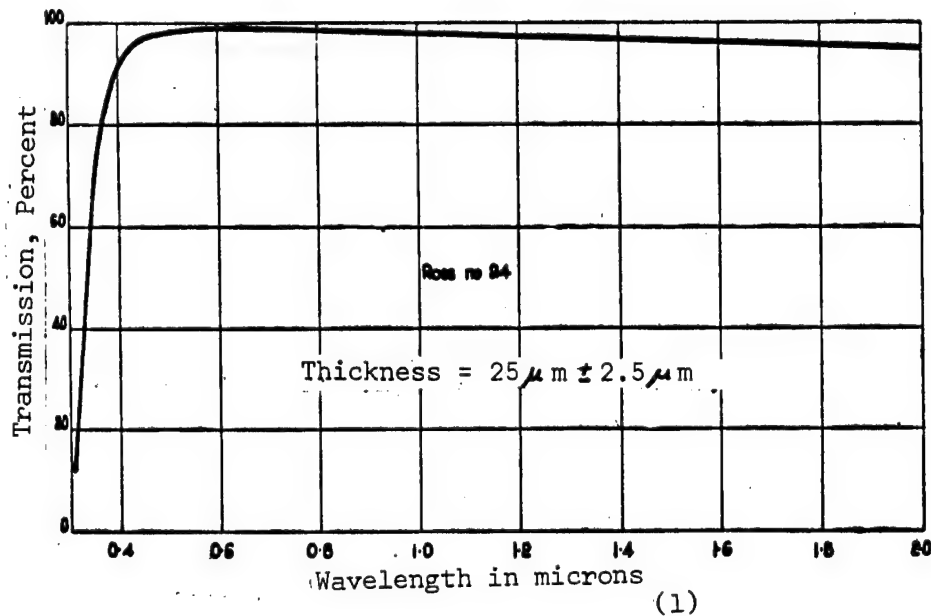
Weight Loss: 3.0 %

Thermal Shock Resistance: Shrinkage after +70°C for 2 hours, -74°C for 1/2 hour, -70°C for 2 hours, room temperature

### OPTICAL PROPERTIES

Refractive Index: 1.46

Clarity: pale yellow



1. Hunt
2. Unit reported by Hunt.

Chemical Type and Composition: Silicone rubber - methyl siloxane, two-component system, room temperature vulcanizing.

Manufacturer: General Electric Co.

#### PROCESSING DATA

Shelf Life: 6 months

Viscosity of Uncured Adhesive: 12 poises

Cure Times: 4 hours at 65°C or 1 hour at 100°C or 15-30 minutes at 150°C

Decementing: Epoxystrip T-254 or Diverstrip WS-1

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 0.99 (cured)

Tensile Strength: 100 psi

Tear Resistance: 10 die B, lb/in (ASTM -D 624)

Linear Shrinkage: <0.2%

Hardness: 15 Shore A Durometer

Elongation: 200%

Brittle Point: <24°C

Peel Strength: 0.15 lb/in

Dielectric Strength: 500 volts/mil (0.075 in. thick)

Dielectric Constant: 3.0 at 60 Hz

Dissipation Factor: 0.001 at 60 Hz

Volume Resistivity:  $1 \times 10^{14}$  ohm-cm

Thermal Conductivity: 0.10 Btu-ft/hr--ft<sup>2</sup> °F at 200°F

Coefficient of Thermal Expansion:  $16.2 \times 10^{-5}/^{\circ}\text{F}$  (0-350°F)

#### OPTICAL PROPERTIES

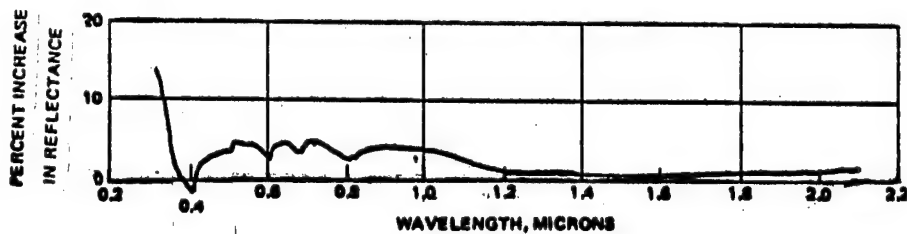
Refractive Index: 1.406

Clarity: Clear

Light Transmission: 91.8 to 94.0% at 0.8  $\mu$  (1)

90.0 to 93.7% at 0.425  $\mu$  (1)

RTV 602 aged in air at 231°C for 24 hours underwent a transmission loss of 16% at 0.45  $\mu$  (2)



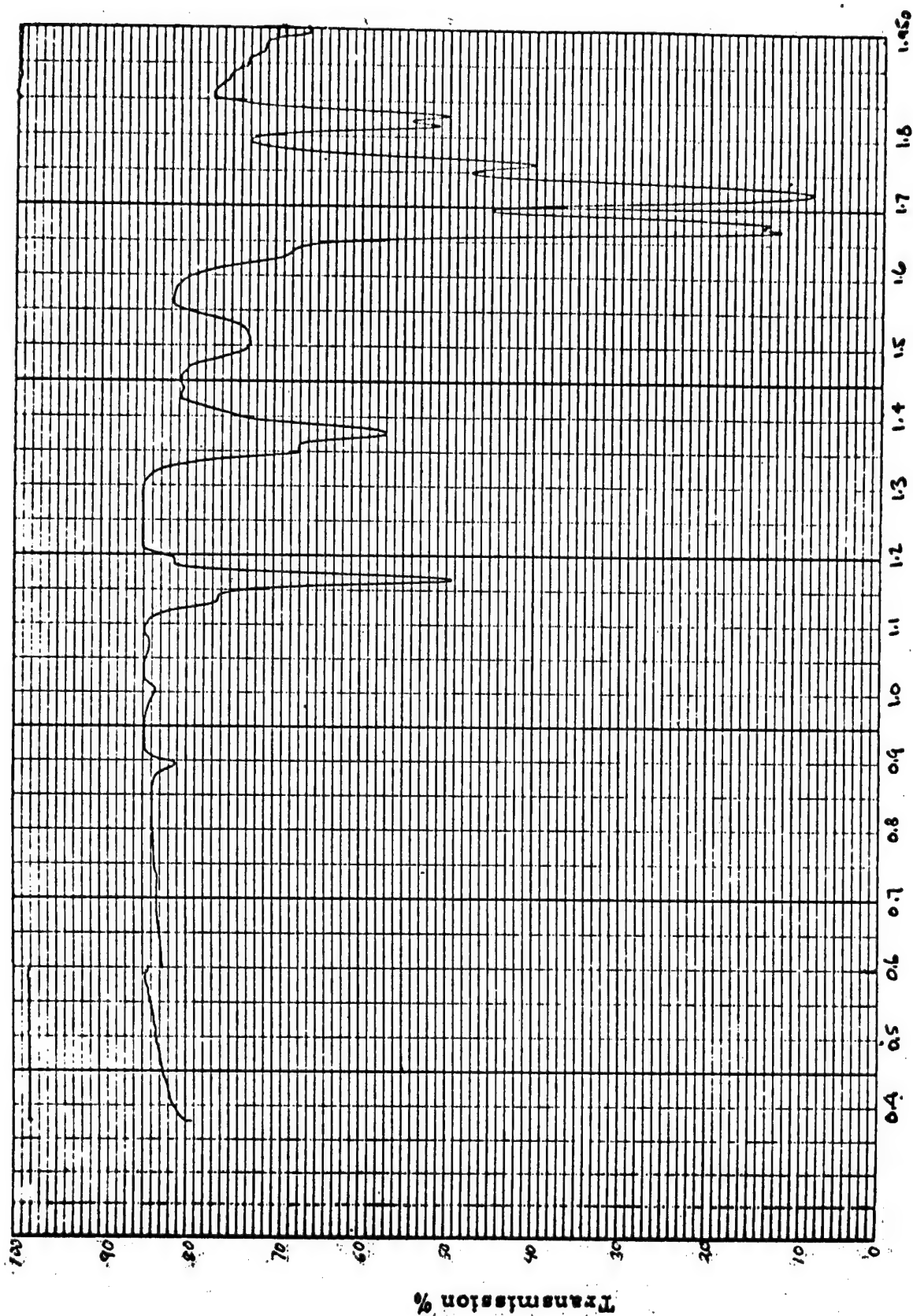
UV Exposure tests of Coverslide Adhesives

450°F for 68 hours at ~4x (Solar UV)

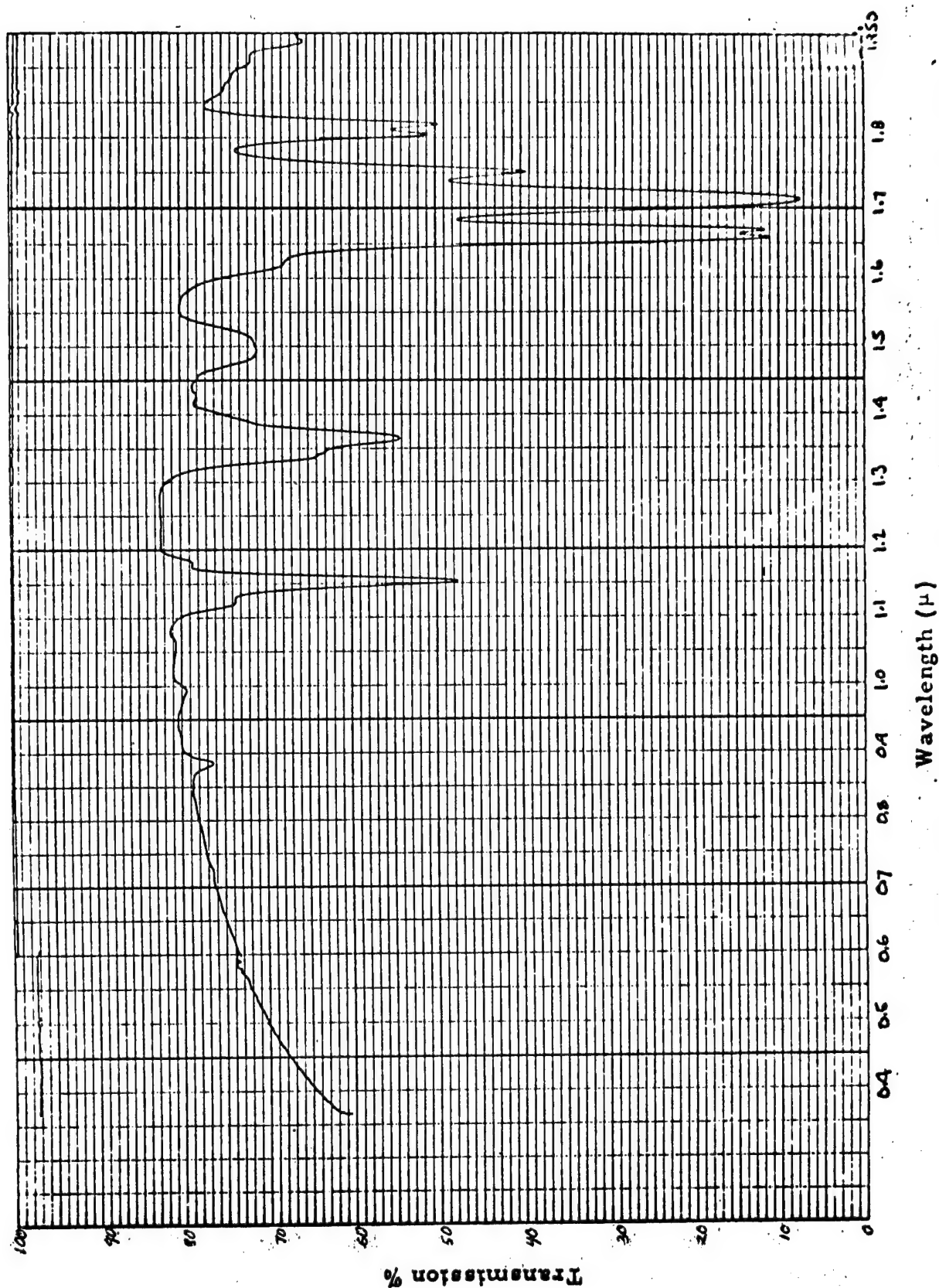
for an equivalent exposure of ~270 hours. (2)

- 
1. Dawson
  2. Schwartz and Cohen
  3. Haynos
  4. General Electric Co., Vendor Literature



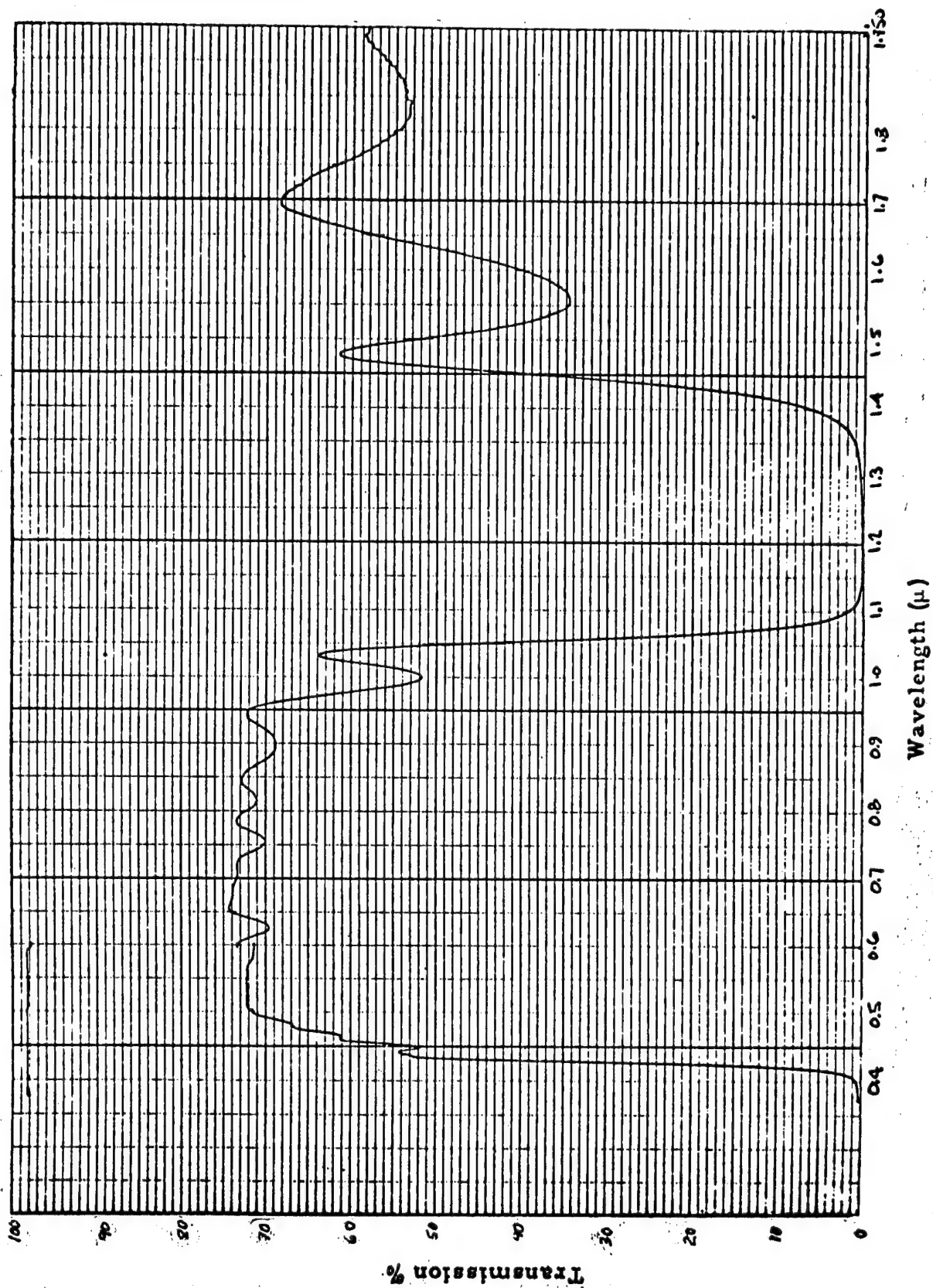


Wavelength (μ)  
Optical transmission curve - unaged RTV-602 adhesive only (2)

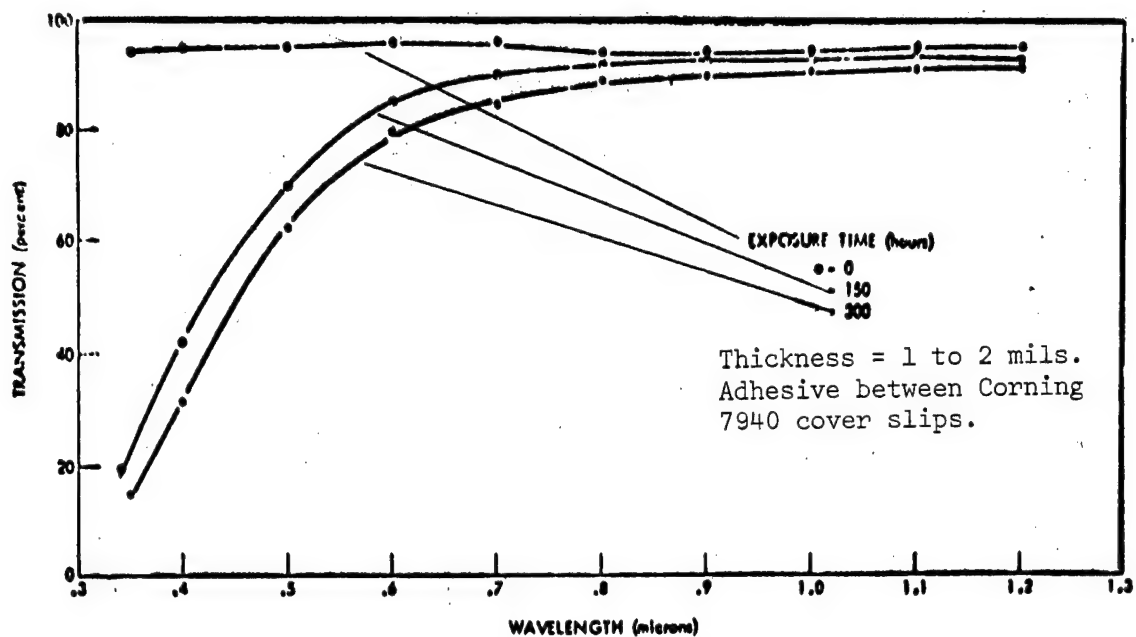


Optical transmission curve - heat aged RTV-602 adhesive only (2)

Aged in air at 231°C for 24 hours

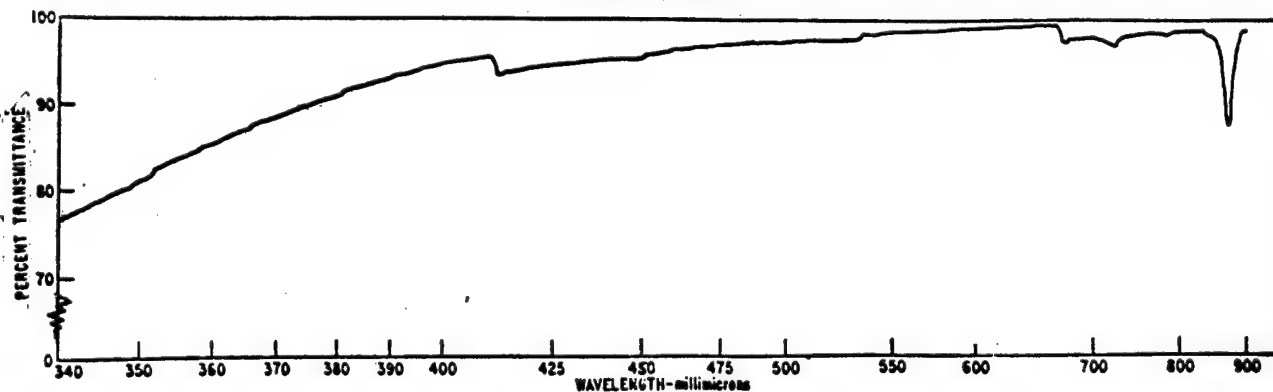
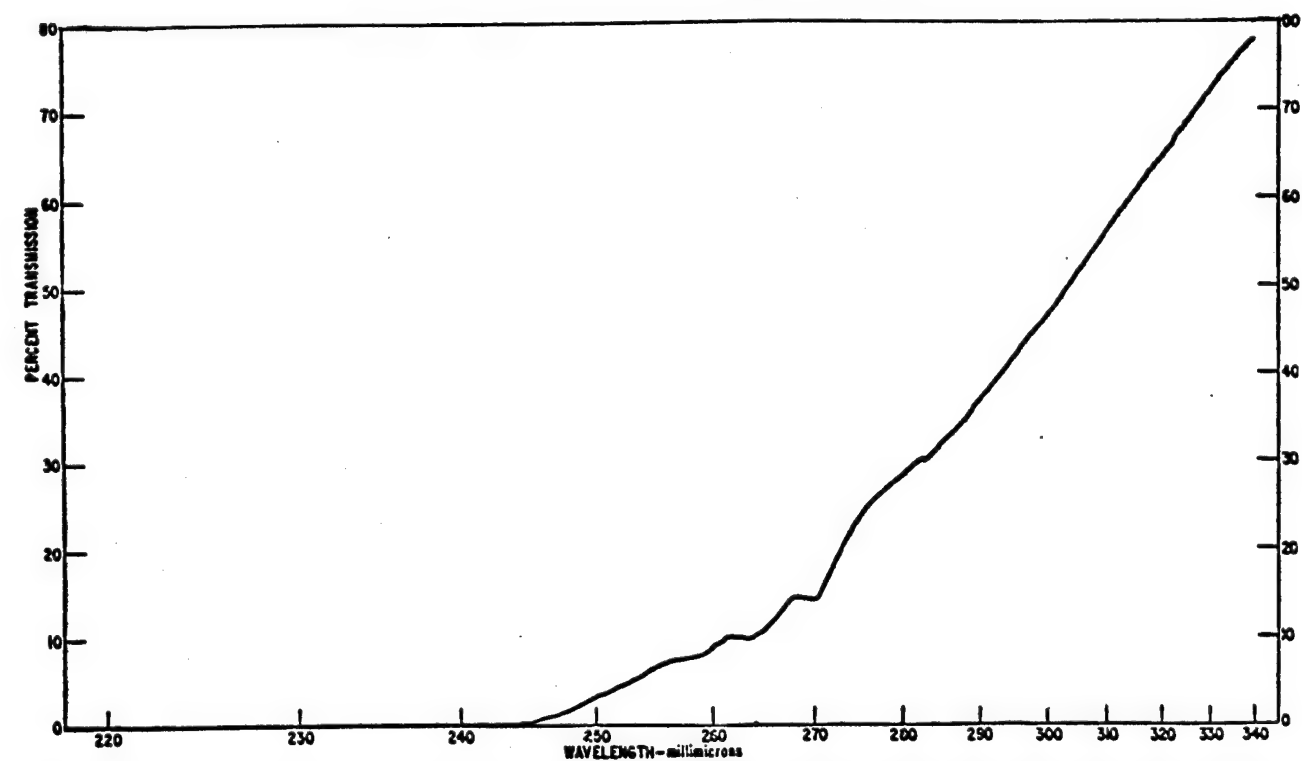


Optical transmission curve - heat aged RTV 602 adhesive between two cover slides (2) Aged in air at 231°C for 24 hours.



Effects of UV Exposure on RTV 602 (3)

UV Source was a 500 watt Hanovia mercury vapor lamp 20 inches in front on the test samples.



RTV 602 Transmission Data - Cured Section (4)

## RTV-615

Chemical Type or Composition: Room temperature vulcanizing silicone rubber, 2-component - methyl siloxane

Manufacturer: General Electric Co., Silicone Products Dept.

### PROCESSING DATA

Shelf Life: 6 months  
Viscosity: 40 poises  
Cure Times: 4 hours at 65°C, 1 hour at 100°C or 15-30 minutes at 150°C  
Decementing: Epoxystrip T-254

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

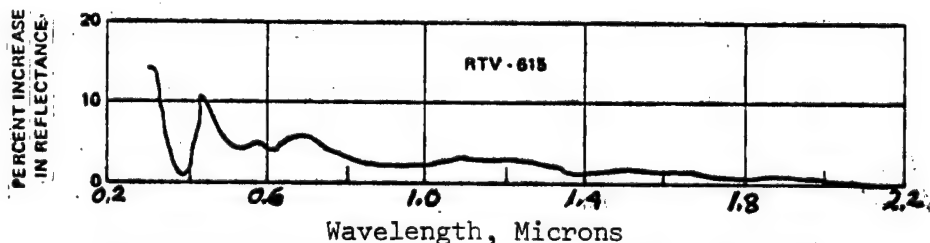
Specific Gravity: 1.02  
Tensile Strength: 925 psi  
Tear Resistance: 25 die B, lb/in  
Linear Shrinkage: < .2%  
Hardness: 35 Shore A Durometer  
Elongation: 150%  
Brittle Point: below -60°C

Dielectric Strength: 500 volts/mil 0.075" thick  
Dielectric Constant: 3.0 at 60 Hz  
Dissipation Factor: .001 at 60 Hz  
Volume Resistivity:  $1 \times 10^{15}$  ohm-cm

Thermal Conductivity: 0.11 Btu-ft/hour ft<sup>2</sup> °F at 200°F  
Coefficient of Thermal Expansion:  $15.3 \times 10^{-5}/^{\circ}\text{F}$  (0-350°F)

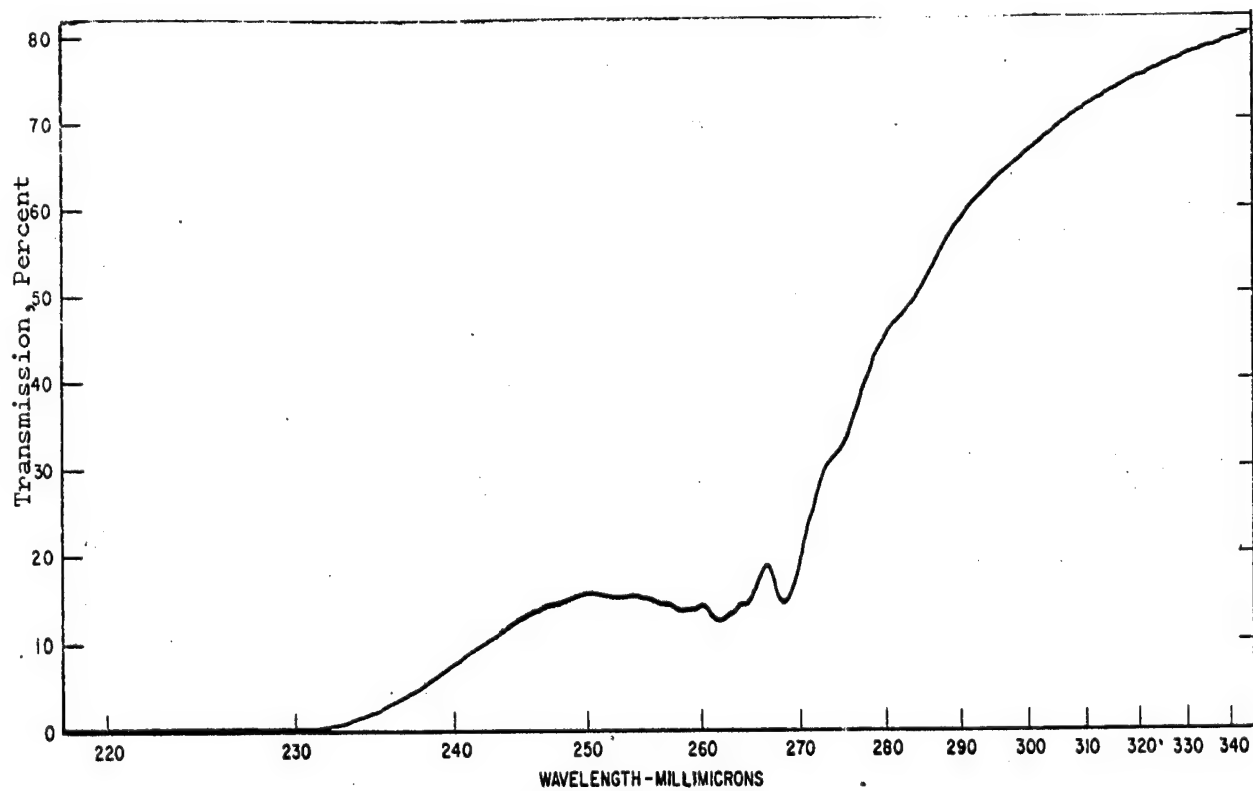
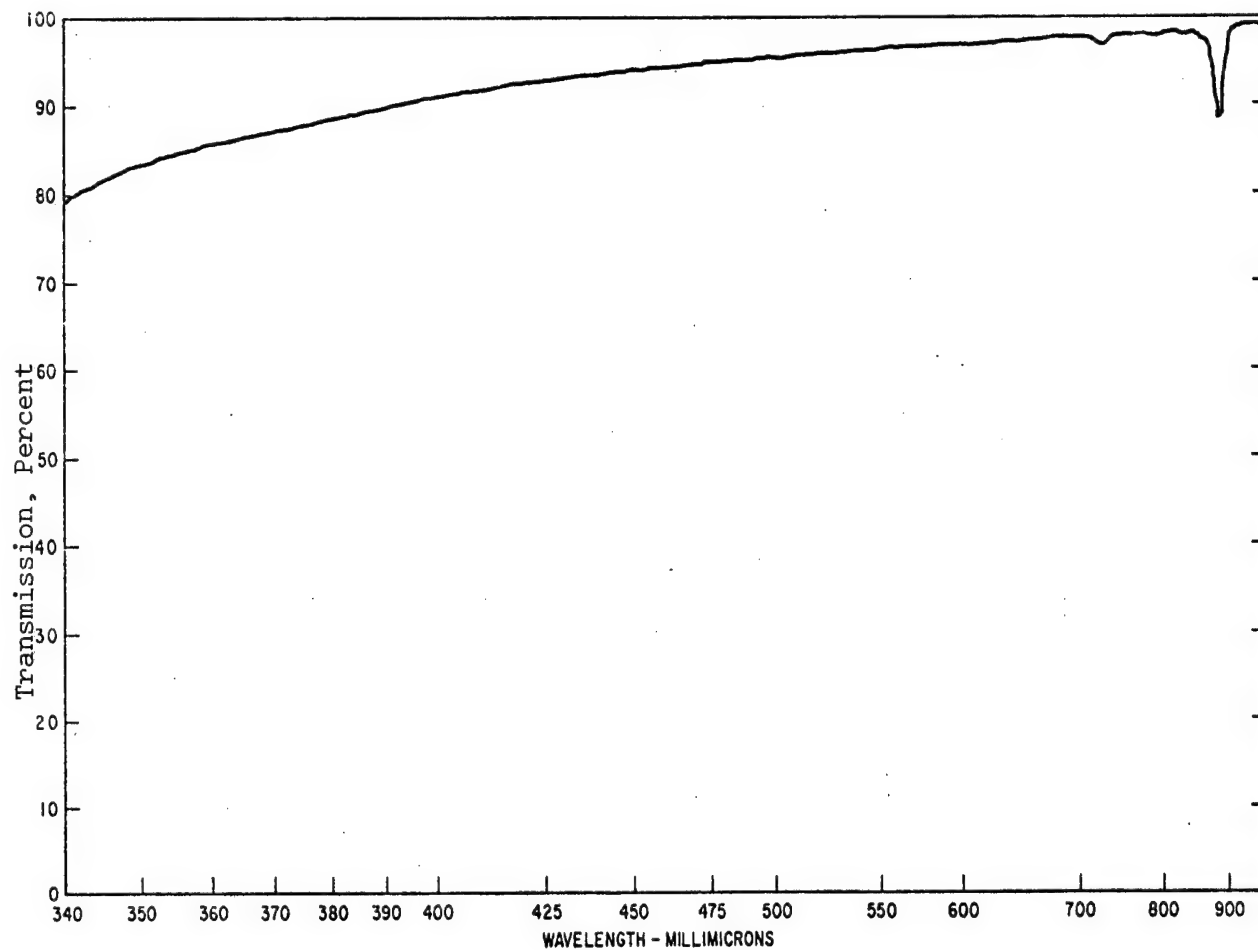
### OPTICAL PROPERTIES

Refractive Index: 1.406  
Clarity: Clear  
Light Transmission: RTV 615 aged for 24 hours in air at 450°F shows a 7% transmission loss at 0.45  $\mu$ .

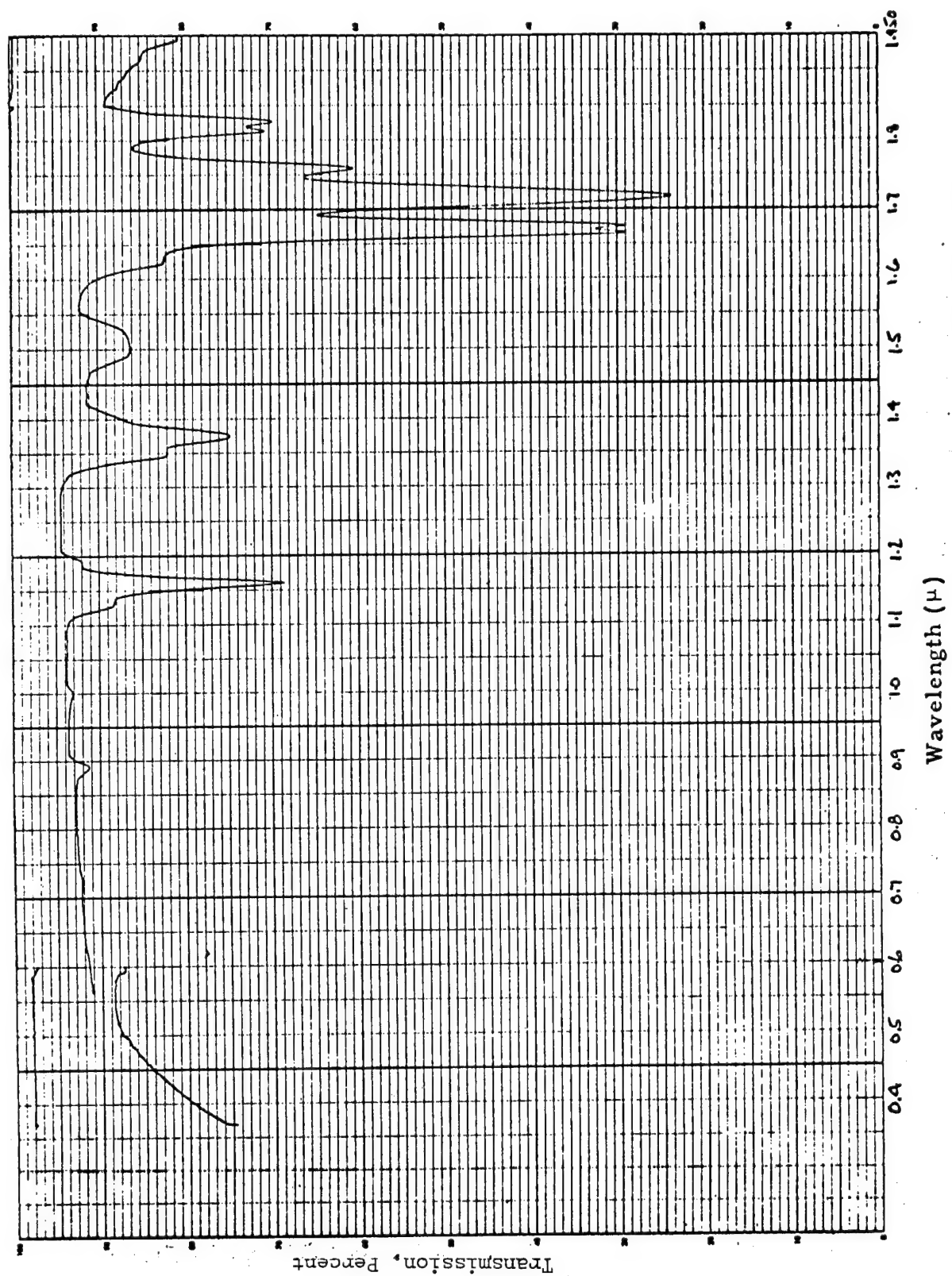


UV Exposure tests of GE RTV-516 Coverslide Adhesive (1)  
450°F for 68 hours at ~4x(Solar UV) for an  
equivalent exposure of ~270 hours.

1. Schwartz and Cohen
2. General Electric Company, Vendor Literature

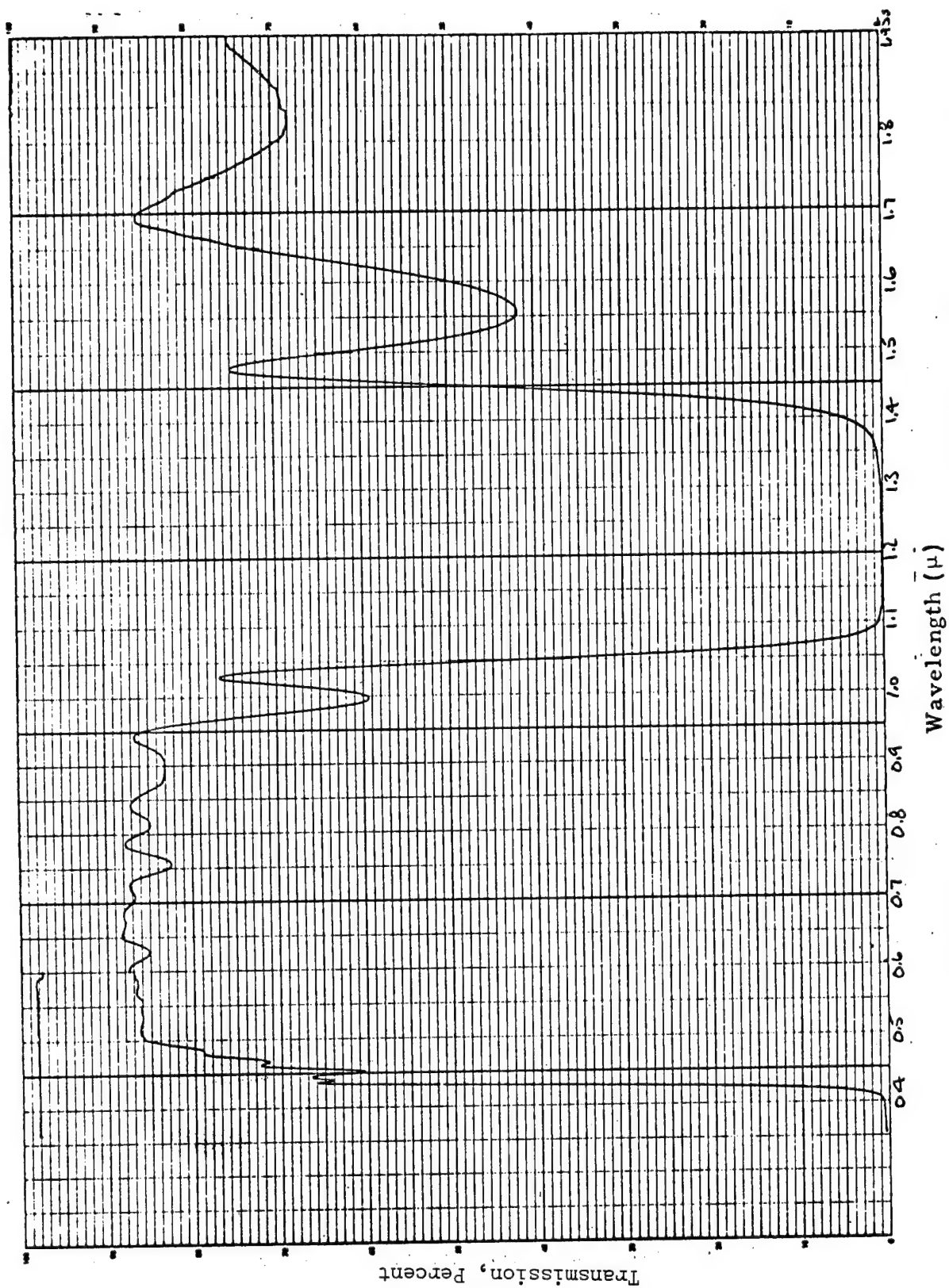


Transmission of GE RTV-615 Cured Section (2)



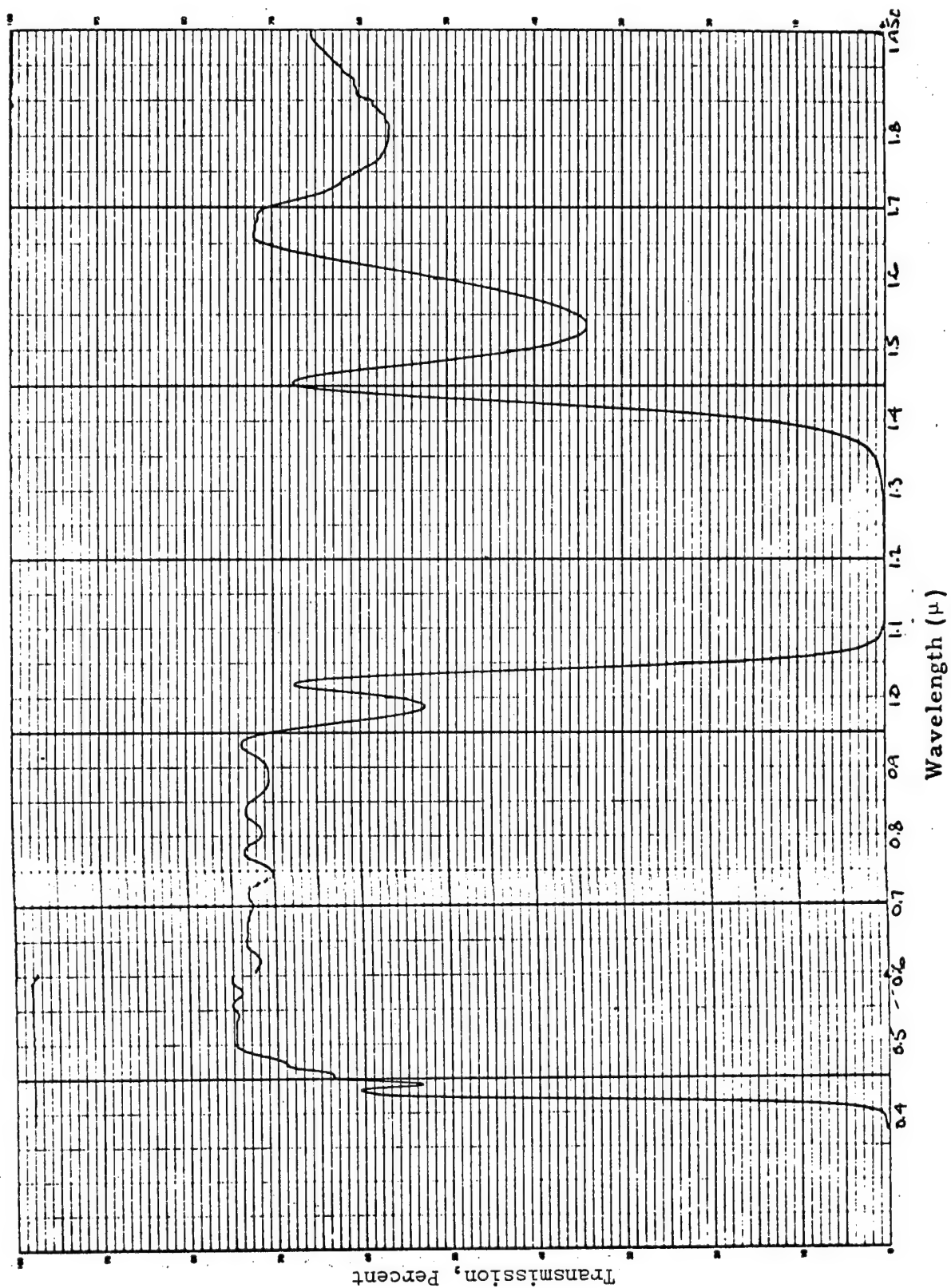
Optical transmission curve - unaged RTV 615 adhesive only (1)



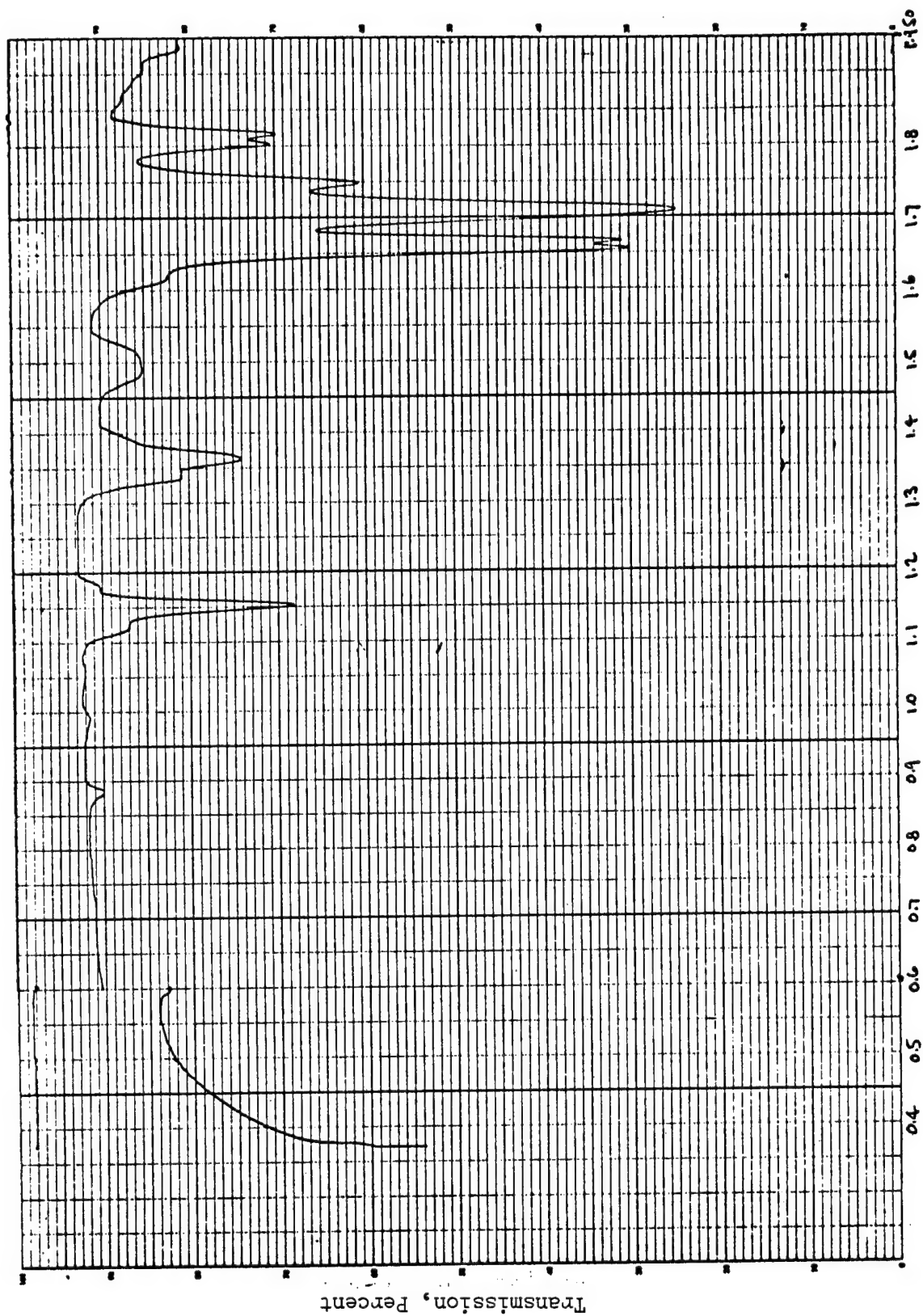


Optical transmission curve - heat aged RTV-615 adhesive between two cover slides (1)





Optical transmission curve - heat aged RTV-615 adhesive G.E. SS-4044  
primer between two cover slides (1)



Optical transmission curve - heat aged RTV 615 adhesive only (1)

# STIXSO DD

Chemical Type or Composition: Sodium silicate,  $\text{Na}_2\text{O}$ , 3.4  $\text{SiO}_2$  molecular composition (1)  
 Approximate Total Solids - 37.8%.  
 Federal Specification O-S-605, Sodium Silicates

Manufacturer: Philadelphia Quartz Company

## PROCESSING DATA

Viscosity: At  $20^\circ\text{C}$ , 2 - 5 poises

## MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.395

Bond Strength:	Tensile		Shear (3)	
	<u>psi</u>	<u>Failure</u>	<u>psi</u>	<u>Failure</u>
	200	Adhesive	400	Adhesive

Tension Bond Strength:  $\text{SiO}_2 / \text{Na}_2\text{O} = 3.3$  (4)  
 Single Coating - 600 psi Double Coating - 800 psi

Volume Resistivity: At  $20^\circ\text{C}$ ,  $\sim 3 \times 10^{10}$  ohm-cm

## OPTICAL PROPERTIES

Refractive Index: At  $0.589\mu$ , 1.495 to 1.500 (6)

Light Transmission: At 430 - 700  $\text{m}\mu$  = 92 - 98 % (2)  
 At 325  $\text{m}\mu$  = 40 %

- 
1. MacFarlane
  2. Silicatos Y Derivados, S.A., Vendor Literature
  3. Moser
  4. Mc Bain
  5. Philadelphia Quartz Company, Vendor Literature
  6. Landolt-Börnstein

## STYCAST 1263

Chemical Type of Composition: Epoxy 2-component  
Manufacturer: Emerson & Cuming, Inc.

### PROCESSING DATA

Pot Life: 24 hours at room temperature  
Viscosity: 880 centipoise  
Cure Times: 16 hours at 107°C  
Service Temperature: 125°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.22  
Flexural Strength: 17,000 psi  
Compressive Strength: 15,500 psi  
Hardness: 86 Shore D

Dielectric Strength: 420 volts/mil  
Dielectric Constant: 1 MHz, 3.4  
Dissipation Factor: 1 MHz, 0.003  
Volume Resistivity: At 25°C,  $10^{15}$  ohm-cm

### OPTICAL PROPERTIES

Refractive Index: 1.54  
Clarity: Light amber

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Emerson & Cuming Inc., Vendor Literature - Clear epoxy casting resin for optical applications. Used for cast optical lenses to exact size and shape.

## STYCAST 1264

Chemical Type or Composition: Epoxy, 2-component

Manufacturer: Emerson & Cuming, Inc.

### PROCESSING DATA

Pot Life: 3 hours

Viscosity: at 25°C 550 centipoise

Cure Times: 48 hours at room temperature or 8 hours at 43°C or 3 hours at 65°C

Service Temperature: 52°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.19

Tensile Strength: 9,500 psi

Flexural Strength: 12,000 psi

Heat Distortion Temperature: 49°C

Compressive Strength: 11,000 psi

Hardness: 78 Shore D

Water Absorption: 0.3% in 24 hours

Dielectric Strength: 400 volts/mil

Dielectric Constant: 60 Hz, 3.7: 1 MHz, 3.3

Dissipation Factor: 60 Hz, 0.008: 1 MHz, 0.006

Volume Resistivity: At 25°C,  $1 \times 10^{14}$  ohm-cm

Coefficient Linear Thermal Expansion:  $70 \times 10^{-6}$  /°F

Thermal Shock Resistance: Passes 10 cycles of MIL-I-16923

### OPTICAL PROPERTIES

Refractive Index: 1.54

Clarity: slight amber

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Emerson & Cuming, Inc., Vendor Literature - Used for laminating glass sheets for safety shields, for cathode ray tubes, and vacuum viewing points.

Chemical Type or Composition: Epoxy 2-component

Manufacturer: Emerson and Cuming, Inc.

#### PROCESSING DATA

Pot Life: 48 hours at room temperature, 8 hours at 65°C  
 Cure Times: 16 hours at 99°C and post cure at 121°C for 4 hours  
 Service Temperature: 150°C

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.22  
 Flexural Strength: 33,000 psi  
 Hardness: 85 Shore D

Dielectric Strength: 430 volts/mil  
 Dielectric Constant: 1 MHz, 3.6  
 Dissipation Factor: 1 MHz, 0.01  
 Volume Resistivity: At 25°C,  $10^{15}$  ohm-cm

Thermal Conductivity: 1.9 BTU-in/hr-ft<sup>2</sup>-°F  
 Coefficient of Thermal Expansion:  $75 \times 10^{-6}/^{\circ}\text{C}$

#### OPTICAL PROPERTIES

Refractive Index: 1.56

Clarity: Colorless

Light Transmission: Percent transmission using a Cary Recording Spectrophotometer Model 14.

Wavelength Å	Thickness	
	175 mils	285 mils
7000	88.5	89.5
6500	85.2	87.0
6000	83.2	85.0
5500	83.0	85.0
5000	82.5	85.0
4500	81.0	82.8
4000	75.9	75.9
3500	47.8	37.1
3000	0	0

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Emerson & Cuming, Inc. Vendor Literature

## SYLGARD 51

Chemical Type and Composition: Silicone

Manufacturer: Dow Corning

### PROCESSING DATA

Shelf Life: 12 months  
Pot Life: 12 hours at 27°C  
Viscosity: 5.8 poises  
Cure Times: 1 hour at 150°C  
Service Temperature: -65 to 200°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

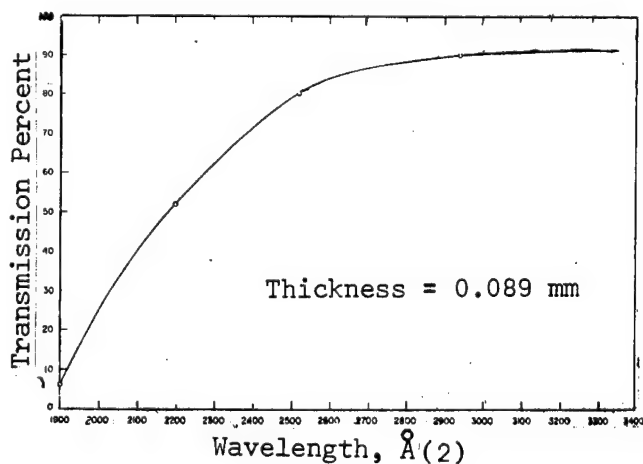
Specific Gravity: 0.97 at 25°C (ASTM D-702 and D-1298)

Dielectric Strength: 500 volts/mil (ASTM D-149)  
Dielectric Constant: 3.0 at 100 Hz (ASTM D-150)  
Dissipation Factor: 0.0005 at 100 Hz (ASTM D-150)  
Volume Resistivity:  $1 \times 10^{15}$  ohm-cm (ASTM D-257)

Thermal Conductivity:  $0.0007 \text{ cal/cm}^2\text{-sec-(}^\circ\text{C/cm)}$  at 25-100°C (Cenco-Fitch)  
Volume Expansion:  $1 \times 10^{-3} \text{ cc/cc -}^\circ\text{C}$  at 25-100°C

### OPTICAL PROPERTIES

Refractive Index: 1.404  
Clarity: Water White



- 
1. Dow Corning Vendor Literature
  2. Pellicori

Chemical Type or Composition: Methyl Siloxane

Manufacturer: Dow Corning

#### PROCESSING DATA

Shelf Life: 12 months

Viscosity: 30 poises

Cure Times: 4 hours at 65°C, or 1 hour at 100°C or 15 minutes at 150°C.

Service Temperature: -65 to 200°C - used in solar cell applications

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 25°C, 1.05

Tensile Strength: 900 psi (ASTM D-412)

Tear Strength: 15 ppi (ASTM D-624)

Linear Shrinkage: 0.1% 3 days at 25°C: 2.1% weight loss at 96 hours at 200°C

Peel Strength: 0.4 lb/in (1)

Hardness: 40 Shore A (ASTM D-676)

Elongation: 100% (ASTM D-412)

Brittle Point: -70°C (ASTM-746)

Dielectric Strength: 550 volts/mil (ASTM D-149)

Dielectric Constant: At 1 MHz - 2.70, at 60 Hz - 2.70, at 3,000 MHz - 2.79 (ASTM D-150)

Dissipation Factor: At 1 MHz - 0.001, at 60 Hz - 0.001, at 3,000 MHz - 0.0120

Volume Resistivity:  $2.0 \times 10^{14}$  ohm-cm (ASTM D-257)

Thermal Conductivity:  $3.5 \times 10^{-4}$  cal/cm<sup>2</sup>-sec (°C/cm) at 25 to 100°C (Cenco-Fitch)

Coefficient of Thermal Expansion:  $3.00 \times 10^{-4}$ /°C at -55 to 150°C

Thermal Shock Resistance: 55°C to 155°C 10 cycles (MIL 1-16923E)

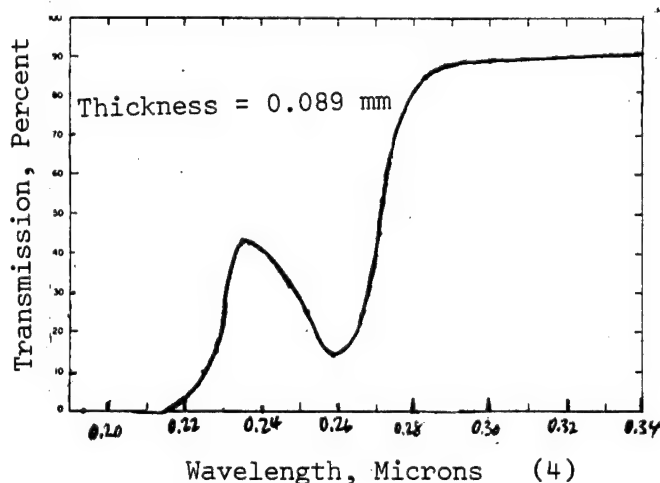
Volume Expansion:  $9.6 \times 10^{-4}$ /°C at 25 to 150°C

#### OPTICAL PROPERTIES

Refractive Index: At 25°C, 1.43

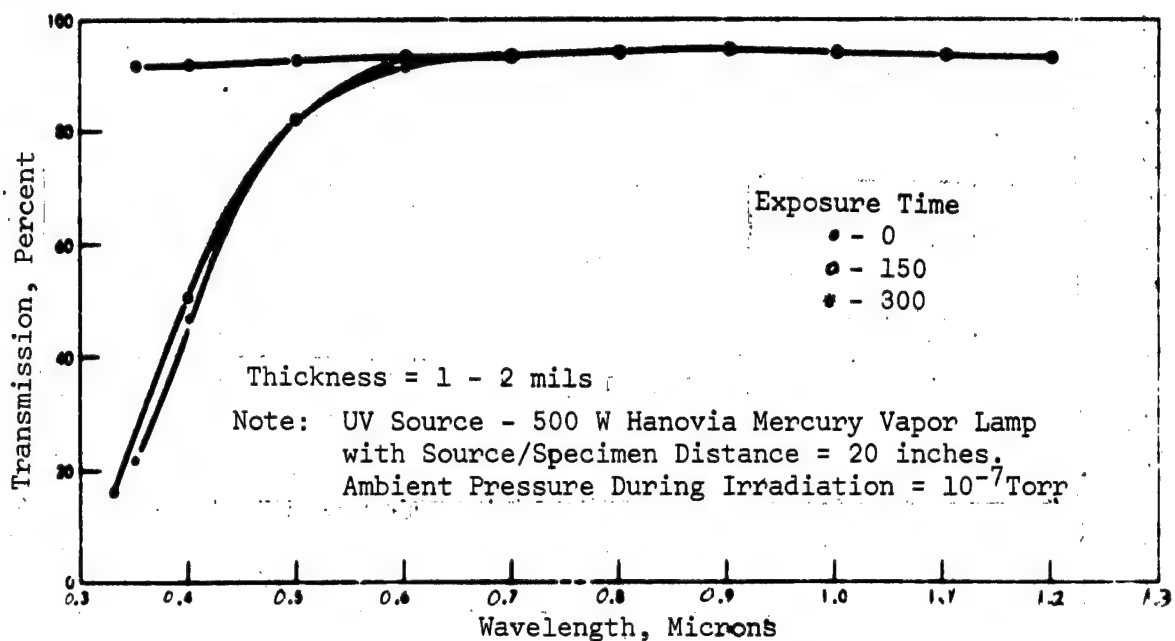
Clarity: Nearly colorless

Light Transmission: 85%



1. Stanley
2. Dow Corning Vendor Literature
3. Haynos
4. Pellicori
5. Moses

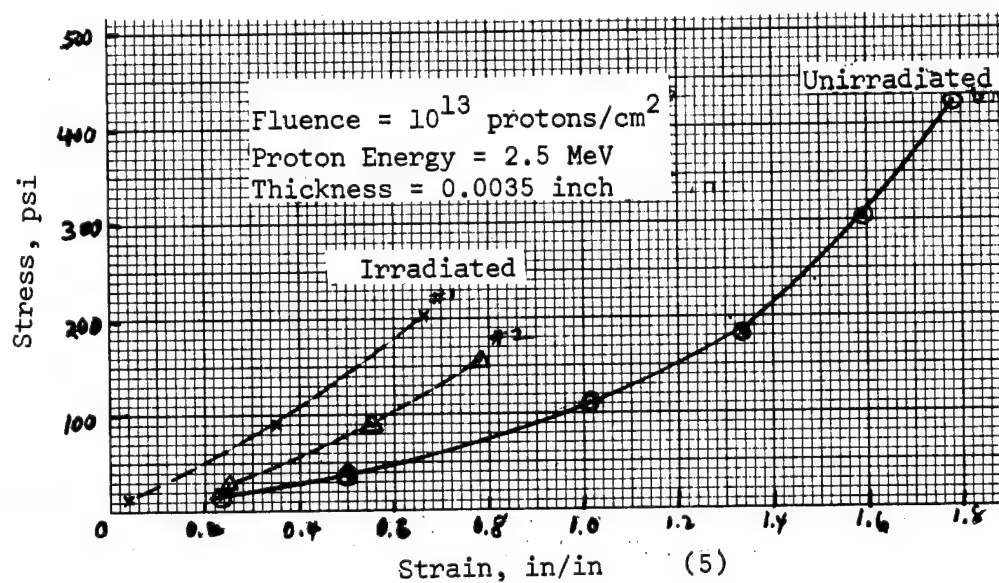




Effects of Ultra-Violet Exposure on Sylgard 182 (3)

Effect of 310 Sun Hours in Vacuum on Sylgard 182 (3)

Sample Thickness mil	Cut-off Point		Absorbance at 350 mμ	
	Before mμ	After mμ	Before	After
69	272.0	279.5	0.095	0.473
69	278.0	281.0	0.063	0.511
73	272.5	281.5	0.086	0.530



Chemical Type or Composition: Silicone

Manufacturer: Dow Corning

#### PROCESSING DATA

Shelf Life: 6 months

Pot Life: 2 hours at 25°C

Viscosity: 30 poises after curing agent added

Cure Times: 24 hours at 25°C: complete cure in 3 weeks (2)

Service Temperature: -65 to 200°C: used in solar cell applications (3)

#### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: 1.05 (ASTM D-702/D1298)

Tensile Strength: 900 psi (ASTM D-412)

Tear Strength: 15 ppi (ASTM D-624)

Weight Loss: 2.1% at 96 hours at 200°C

Shrinkage: nil at 3 days at 25°C

Hardness: 35 Shore A (ASTM D-676)

Elongation: 100% (ASTM D-412)

Brittle Point: -120°C (ASTM D-746)

Dielectric Strength: 550 volts/mil (ASTM D-149)

Dielectric Constant: 2.75 at 60 Hz, 2.75 at 1 MHz (ASTM D-850)

Dissipation Factor: 0.001 at 60 Hz, 0.001 at 1 MHz (ASTM D-150)

Volume Resistivity:  $1 \times 10^{14}$  ohm-cm (ASTM D-257)

Thermal Conductivity:  $3.5 \times 10^{-4}$  cal/cm<sup>2</sup>-sec-(°C/cm) (Cenco-Fitch)

Volume Expansion:  $9.6 \times 10^{-4}$ /°C at 25 to 150°C

Thermal Shock Resistance: 10 cycles at 55° to 155°C (MIL 1-16923E)

#### OPTICAL PROPERTIES

Refractive Index: 1.43 at 25°C (ASTM D-1218)

Clarity: Clear

- 
1. Dow Corning Vendor Literature
  2. Stanley
  3. Curtin

## URALANE X-87174A/B

**Chemical Type or Composition:** Urethane, 2 components

**Manufacturer:** Furane Plastics, Inc.

### PROCESSING DATA

**Pot Life:** 20-30 minutes at 25°C  
**Viscosity:** At 25°C 6,000-10,000 centipoise  
**Cure Times:** 30 minutes at 66°C  
**Service Temperature:** Cryogenic to 66°C

### MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

**Tensile Strength:** 2000-4000 psi depending on cure time and temperature  
**Hardness:** 70-80 Durometer-A - depending on cure time and temperature  
**Elongation:** 450%

### OPTICAL PROPERTIES

**Clarity:** Clear

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Furane Plastics Vendor Literature - Used for bonding unsanded polycarbonate, polysulfone and acrylic with gap filling properties. Bonded joints offer optical clarity.

## WYNDHAM OPTICAL CEMENT

**Chemical Type or Composition:** 2 component epoxy, exothermic

**Manufacturer:** Wyndham Chemicals, Inc.

### PROCESSING DATA

**Shelf Life:** 1 year  
**Pot Life:** 14 to 16 minutes/100 grams  
**Viscosity:** 37-128 Resin at 27°C 300-500 cps (Brookfield)  
37-600 Hardener at 25°C 4000-6000 cps  
**Cure Times:** 7 days at room temperature or 4 days at room temperature  
plus one day at 49°C.  
**Service Temperature:** Pyrex and EDF-4 glasses bonded with the adhesive  
for use in a lens system failed at -30°C. (2)

- 
1. Wyndham Chemicals Vendor Literature
  2. Turini

**Chemical Type or Composition:** Methyl Siloxane, Controlled form of Sylgard 184

**Manufacturer:** Dow Corning

**PROCESSING DATA**

**Shelf Life:** 6 months

**Pot Life:** 2 hours with curing age

**Viscosity:** 5000 centistokes

**Cure Times:** 72 hours at 25°C

**Service Temperature:** -65 to 200°C, used in solar cell applications (2)

**MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES**

**Specific Gravity:** At 25°C, 1.05

**Tensile Strength:** 600 psi

**Weight Loss:** 1.6% after 1000 hours at 150°C

**Hardness:** 35 Shore A

**Elongation:** 100%

**Brittle Point:** -135°C

**Dielectric Strength:** 500 volts/mil

**Dielectric Constant:** 100 Hz, 2.88: 10 KHz, 2.88

**Dissipation Factor:** 100 Hz, 0.002: 10 KHz, 0.002

**Volume Resistivity:**  $1 \times 10^{14}$  ohm-cm

**Thermal Conductivity:**  $3.5 \times 10^{-4}$  cal/cm<sup>2</sup> (°C/cm) sec.

**Thermal Shock Resistance:** -55 to 155°C 10 cycles

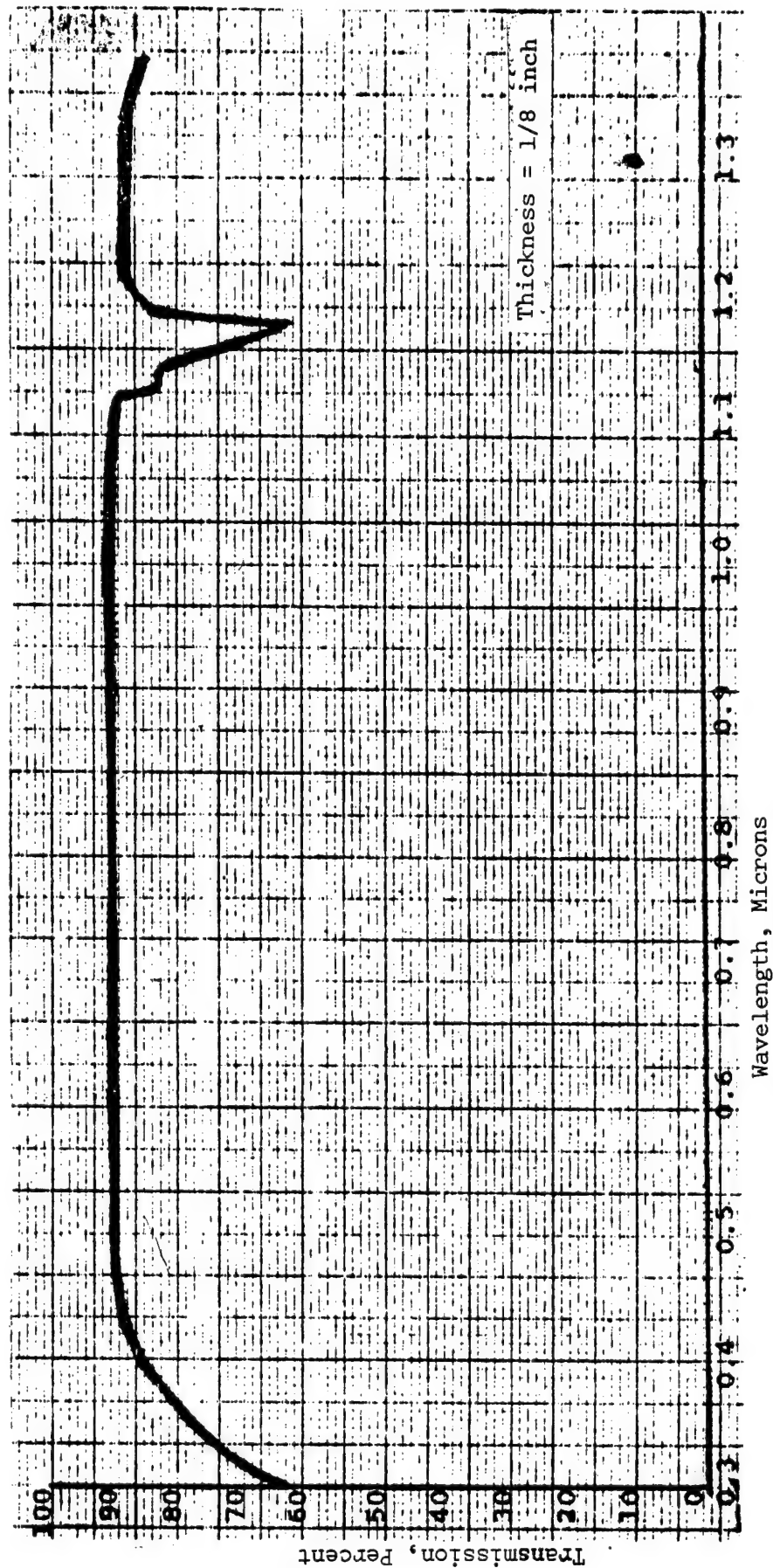
**OPTICAL PROPERTIES**

**Refractive Index:** 1.430

**Clarity:** Clear

**Light Transmission:** 85%

- 
1. Dow Corning Vendor Literature
  2. Curtin



Approximate Light Transmission of Typical DOW CORNING XR-63-488 (1)

XR-63-489

Chemical Type and Composition: Methyl Siloxane - Controlled form of Sylgard 182

Manufacturer: Dow Corning

PROCESSING DATA

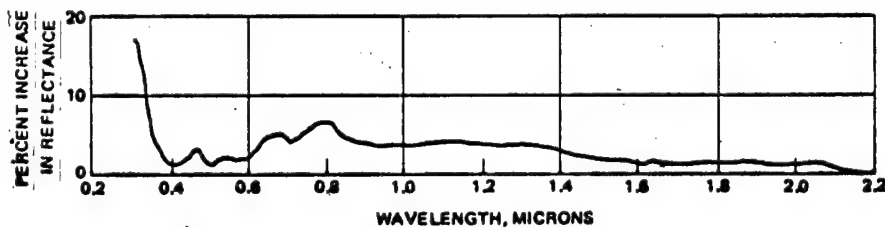
Shelf Life: 12 months                      Pot Life: 8 hours  
Viscosity of Uncured Adhesive: 5000 centistokes at 25°C  
Cure Times: 4 hours at 65°C or 1 hour at 150°C  
Service Temperature: -65 to 200°C

MECHANICAL, ELECTRONIC AND THERMAL PROPERTIES

Specific Gravity: At 25°C, 1.02  
Tensile Strength: 900 psi  
Linear Shrinkage: 1.6% after 1000 hours at 150°C  
Hardness: 40 Shore A  
Elongation: 100 %  
Brittle Point: -135°C  
  
Dielectric Strength: 500 volts/mil  
Dielectric Constant: 100 Hz, 2.88: 10 KHz, 2.88  
Dissipation Factor: 100 Hz, 0.002: 10 KHz, 0.002  
Volume Resistivity:  $1 \times 10^{14}$  ohm-cm  
Thermal Conductivity:  $3.5 \times 10^{-4}$  cal/cm<sup>2</sup> (°C/cm)sec  
Thermal Shock Resistance: 10 cycles of -55 to 155°C

OPTICAL PROPERTIES

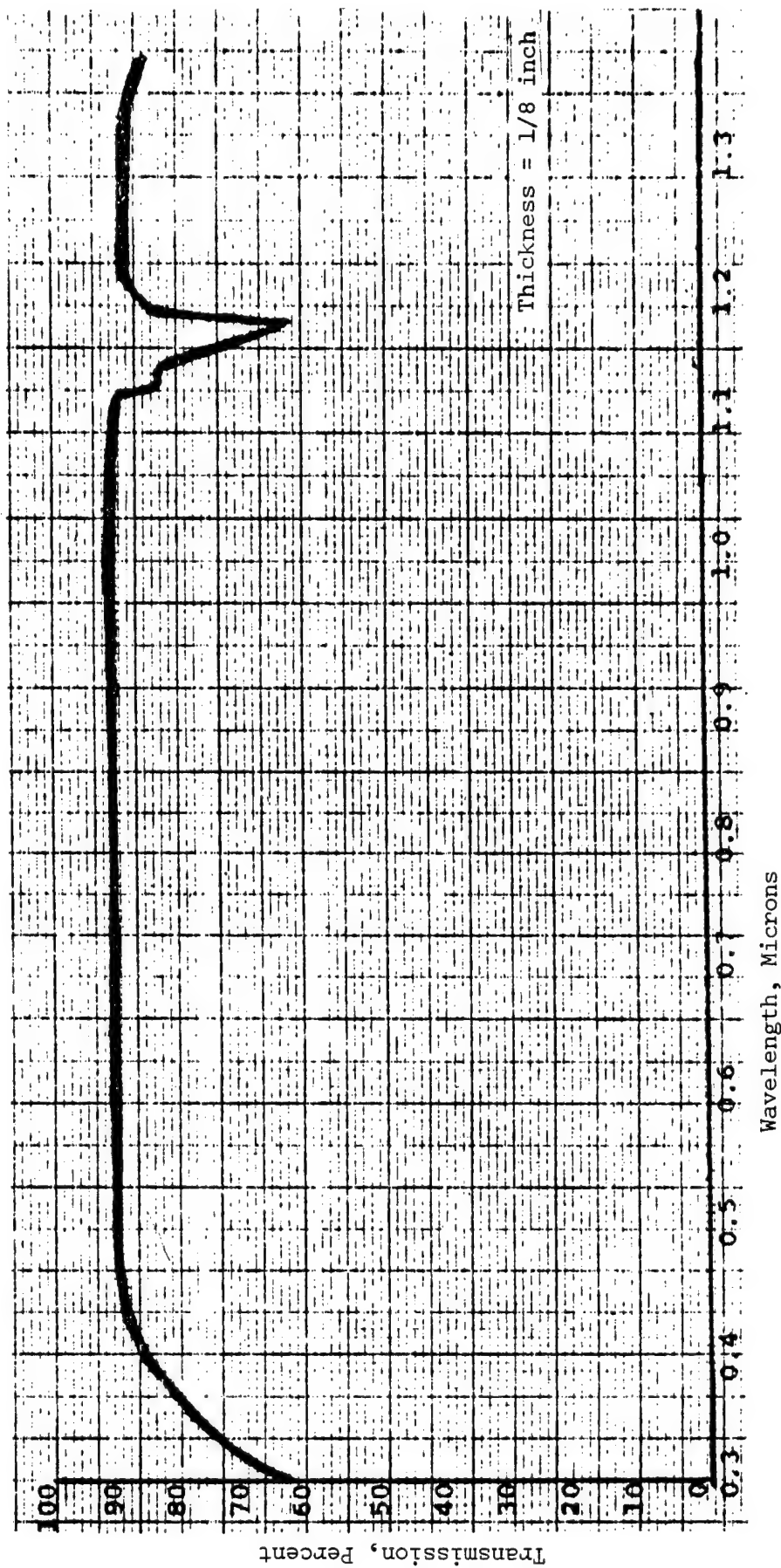
Refractive Index: 1.430  
Clarity: Clear  
Light Transmission: 91.0 to 94.0 % at 0.8 $\mu$  (1)  
89.9 to 93.7 % at 0.425 $\mu$



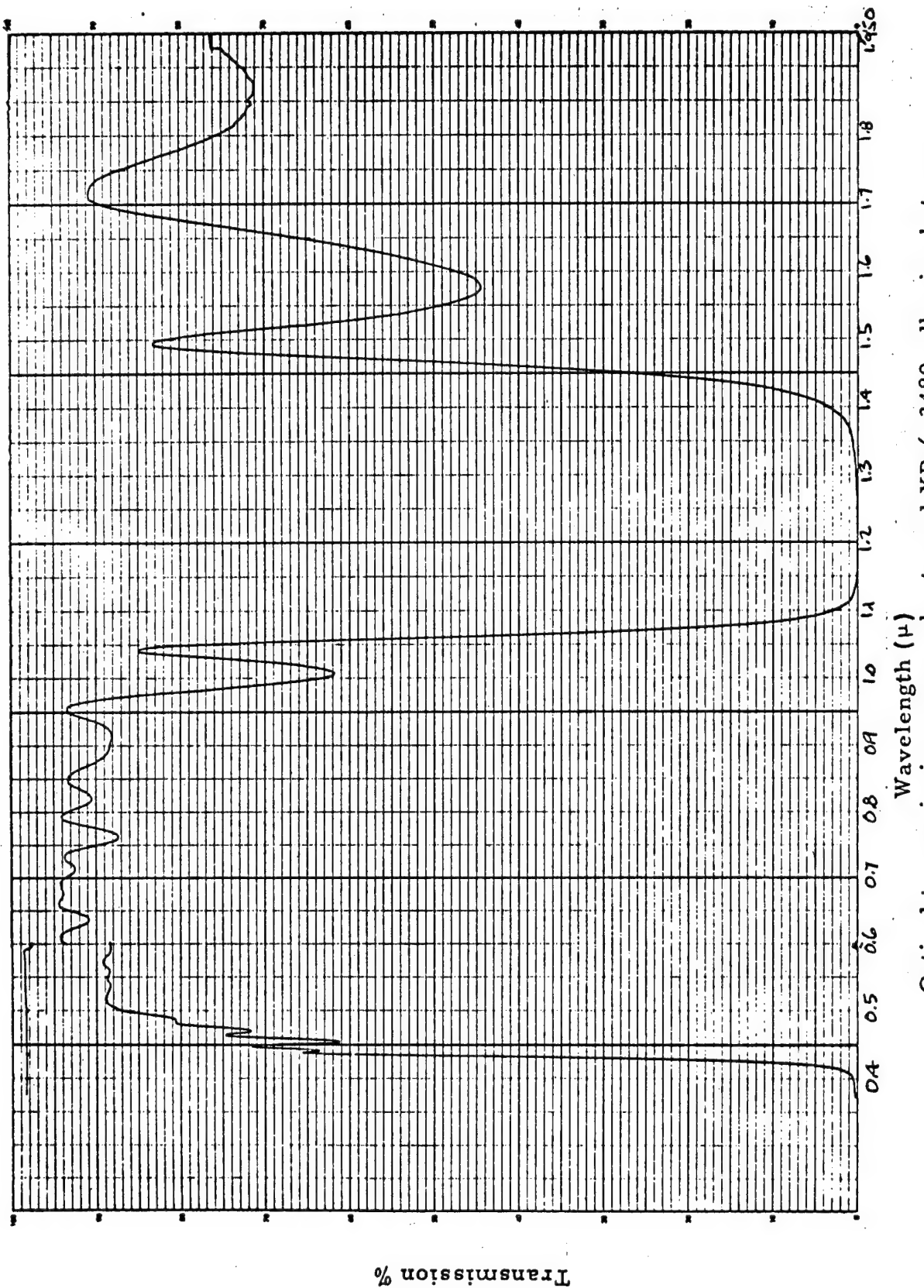
UV Exposure Tests of Coverslide Adhesives (2)

450°F for 68 hours at ~ 4X(Solar UV) for an  
equivalent exposure of ~ 270 hours.

1. Dawson
2. Schwartz and Cohen
3. Dow Corning Vendor Literature

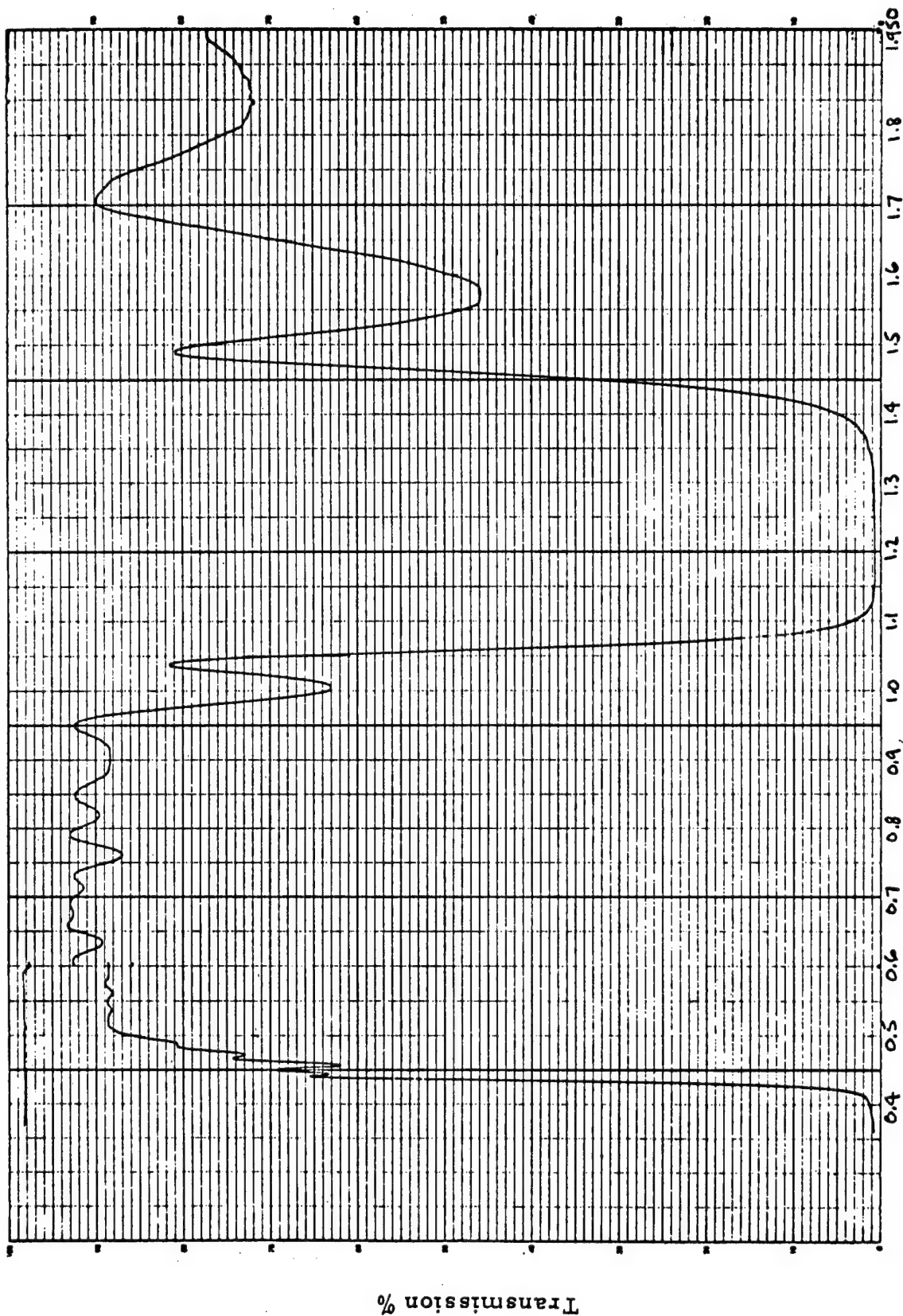


Approximate Light Transmission of Typical DOW CORNING XR-63-489 (3)

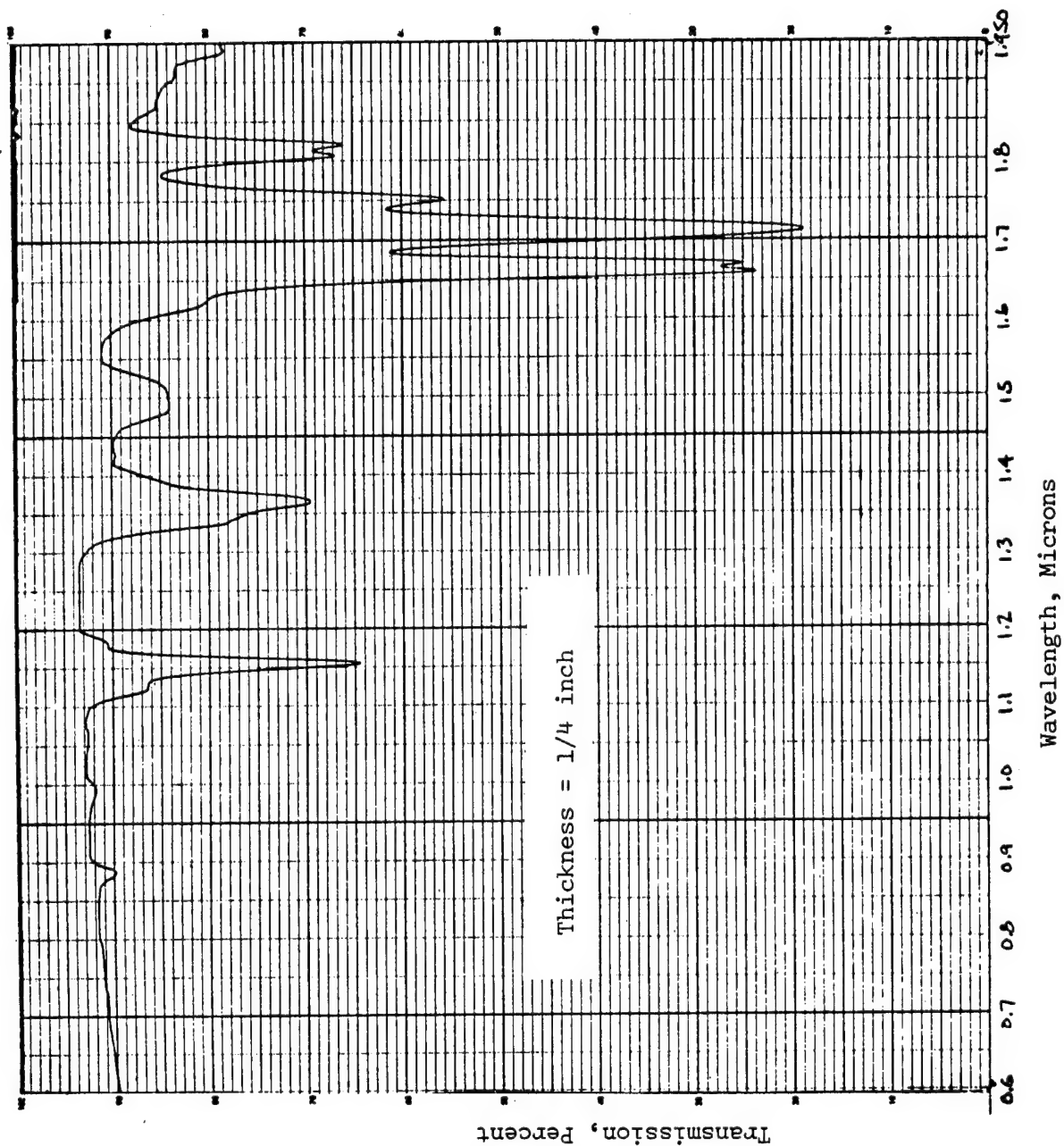


Optical transmission curve - heat aged XR 6-3489 adhesive between two cover slides (2)





Wavelength ( $\mu$ )  
 Optical transmission curve - heat aged XR 6-3489 adhesive and Dow  
 Sylgard primer between two cover slides (2)



Optical Transmission Curve - Heat Aged XR-63-489 Adhesive Only (2)

Note: Heat Aged 24 hours at 450°F in Air.

## BIBLIOGRAPHY

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APPENDIX I  
MANUFACTURERS OF  
TRANSPARENT OPTICAL ADHESIVES



MANUFACTURERS OF TRANSPARENT  
OPTICAL ADHESIVES

MANUFACTURER	ADHESIVE
American Optical Corporation Scientific Instrument Division 10 Optical Ave. Keene, N.H. 03431	AO-805
Barr & Stroud Limited Caxton Street Anniesland Glasgow, Scotland	B & S No. 8
B.I.P. Chemicals Limited Popes Lane Oldbury P.O. Box 6 Warley, Worcs. England	BEETLE 4128
CIBA Products Company 556 Morris Ave. Summit, N.J. 07901	ARALDITE 502
Cominso Limited 351 Pl. Royale Montreal, Quebec Canada	CANADA BALSAM
Dow Corning Corporation Midland, Michigan 48640	DC 200 GLYCERINE SYLGARD 51 SYLGARD 182 SYLGARD 184 XR-63-488 XR-63-489
Eastman Chemical Products, Inc. Chemicals Division Kingsport, Tenn. 37662	EASTMAN 910
Eastman Kodak Company Rochester, N.Y. 14650	HE-2 HE-10 HE-63 HE-65 HE-79 HE-100 B HE-100 X HE-F-4

MANUFACTURER	ADHESIVE
Emerson & Cuming, Inc. Canton, Mass. 02021 Gardena, Calif. 90247 Northbrook, Ill. 60062	ECCOBOND 24 ECCOGEL 1265 STYCAST 1263 STYCAST 1264 STYCAST 1269 A
Epoxy Technology Inc. 65 Grove Street Watertown, Mass. 02172	EPO-TEK 301 EPO-TEK 305
Fisher Scientific Co. 1458 N. Lamon Ave. Chicago, Ill.	CANADA BALSAM
Furane Plastics, Inc. 5121 San Fernando Rd. West Los Angeles, Calif. 90039 16 Spielman Rd. Fairfield, N.J. 07007	EPOCAST 253 (Formerly 15E) EPOCAST H-1368/9313 URALANE X-87174 A/B
General Electric Co. Silicone Products Department Waterford, N.Y. 12188	RTV 602 RTV 615
Hopkin & Williams Division of Baird & Tatlock, Ltd. P.O. Box 1 Romford, R.M. 1 1 HA Chadwell Heath, Essex England	H.T. CEMENT
Maas & Waldstein Co. 2121 McCarter Highway Newark, N.J. 07104	CELLULOSE CAPRATE
Merck and Company, Inc. Rahway, N.J.	GLYCERINE
Monsanto Company St. Louis , Mo. 63166	GELVA
Opticon Chemical Division of Dynalysis, Inc. P.O. Box 2445 Palos Verdes Peninsula, Calif. 90274	OPTICON SFA-23 OPTICON UV-57
Philadelphia Quartz Company Public Ledger Building Philadelphia, Pa. 19106	STIXSO DD
PPG Industries, Inc. Chemical Division One Gateway Center Pittsburgh, Pa. 15222	CR-39

MANUFACTURER	ADHESIVE
Ross Limited Clapham Common North Side London S.W. 4 England	ROSS OPTICAL CEMENT No. 24
Shell Chemical Company, Ltd. Villiers House 41-47 Strand London W.C. 2 England	EPIKOTE 817
Summers Laboratories, Inc. Fort Washington, Pa. 19034	LENS BOND C-59 LENS BOND F-65 LENS BOND M-62 LENS BOND U-69
Swift and Company 115 W. Jackson Blvd. Chicago, Ill. 60604	GLYCERINE
Transene Company, Inc. Route 1 Rowley, Mass. 01969	EPOXY-20 ADHESIVE
Wyndham Chemicals, Inc. 10640 S. Painter Ave. Santa Fe Springs, Calif. 90670	WYNDHAM OPTICAL CEMENT